Transactions of the

AMERICAN FOUNDRYMEN'S ASSOCIATION

PROCEEDINGS OF THE
TWENTY-EIGHTH ANNUAL MEETING
MILWAUKEE, WISCONSIN
OCTOBER 13 TO 16, 1924

Volume XXXII
Part II

Papers and
Committee Reports on Sand Research
Presented at the Milwaukee Meeting
and Report of
Geological Survey of Sand Resources

EDITED BY ROBERT E. KENNEDY

PUBLISHED BY THE
AMERICAN FOUNDRYMEN'S ASSOCIATION
CHICAGO, ILLINOIS
1925

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Contents

(Part II)

NOTE: **The tentative standard methods of testing referred to in these papers will be found in the A. F. A.** ***Transactions,*** **Vol. 31, pp. 687-749, 1924, and in** ***The Resumé of the Activities of the Joint Committee on Molding Sand Research,*** **June 1, 1924.**

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Molding Sand Reclamation and Control Experiments

F. L. WOLF AND A. A. GRUBB, MANSFIELD, OHIO

Late in 1922 The Ohio Brass Company started experiments with a view to reclaiming waste sands which were passing from their brass foundry to the dump. An account of the preliminary work and first practical trials were given in a report entitled "Brass Molding Sand Reclamation and Conservation Experiments,"[1] at the Cleveland Convention of this Association in 1923. Two molding floors were operated entirely on reclaimed sand during the following summer, and, with other floors operated on new sands, were carefully observed. An account of these trials and observations was reported[2] to the committee in October, 1923. The present paper deals with further experiments along this line, the extension of reclamation work and sand control methods to our entire brass foundry and the effect on molding losses.

Reclamation Experiments

The refuse sand which we have been reclaiming consists of the fine material from foundry floor sweepings. The cores, core wires, scrap brass and spillings are hand picked and screened out with aid of an eight mesh screen. About 260 pounds of this fine material are produced each week by each floor. It has a bond value of about 135, a figure entirely too low for molding purposes.

In our first experiments at reclaiming this sand, it was mixed with fine medium bond sand from Northern Ohio. This served to build up its bond but also tightened the sand. The grain size was too small. A high bond but larger grained material was needed. The Gallia County (Ohio) red sands offered

[1] *Transactions* A. F. A., Vol. 31, pp. 649-655.
[2] *Bulletin* A. F. A., Vol. 3, January, 1924, pp. 19-21.

possibilities so were tried out experimentally. Table 1 lists data on several sands used successfully in the experiments. The figures are average values. The local No. 1 and No. 2 sands are produced in Northern Ohio and were used as substitutes for the No. 1 and No. 2 Albany sands because of lower freight rates. The class of work made in our foundry requires a bond value between 150 and 180 grams and permeability between 17 and 25 depending on the job. The grain size of the local No. 2 and the Gallia sands appealed to us because they tended to keep the heaps open.

Table No. 1

	Heap Sand.	Refuse Sand.	Albany No. 1	Albany No. 2.	Local No. 1.	Local No. 2.	Gallia.
Permeability	20	23	20	40	19	45	103
Bond	160	135	170	155	165	153	355
Tensile strength....	128	92	150	125	140	120	751
Fineness of grain..	134	125	150	105	178	87	86
Clay (A. F. A.)....	7	6	8	7	8	9	27
Clay (vibratory))..	25	20	18	14	21	9	74
Dye adsorption......	130	110	160	160	220	260	1700

A number of combinations were made up and examined. Gallia sand was mixed with the refuse to renew its bond. The local No. 1 sand was added to reduce grain size and tighten the sand for smooth surfaces, while the No. 2 sand was used when greater permeability was required. The mixtures were tried out on experimental molding floors under close observation. The quality of lift and the number of stickers, drops, etc., were noted and casting losses due to dirt and misruns were observed. The mixtures and rebuilds best suited to the requirements of the work were thus studied.

Intimate mixtures were made by passing the sand several times through coarse riddles or through a Royer machine. This latter is a motor driven cleaning and mixing device. Its action is similar to that of a riddle. It has no rubbing or mulling effect. Neither the screens nor the Royer developed the bond in the sand even when the operations were repeated several times. The rolling and rubbing action of a muller was required to bring out the strength. A small No. 0 muller was supplied by the National Engineering Company of Chicago for use in these tests and has proven very valuable.

Data from these experiments are given in Table 2 and the chart Fig. 1. Various sands and combinations of sands were

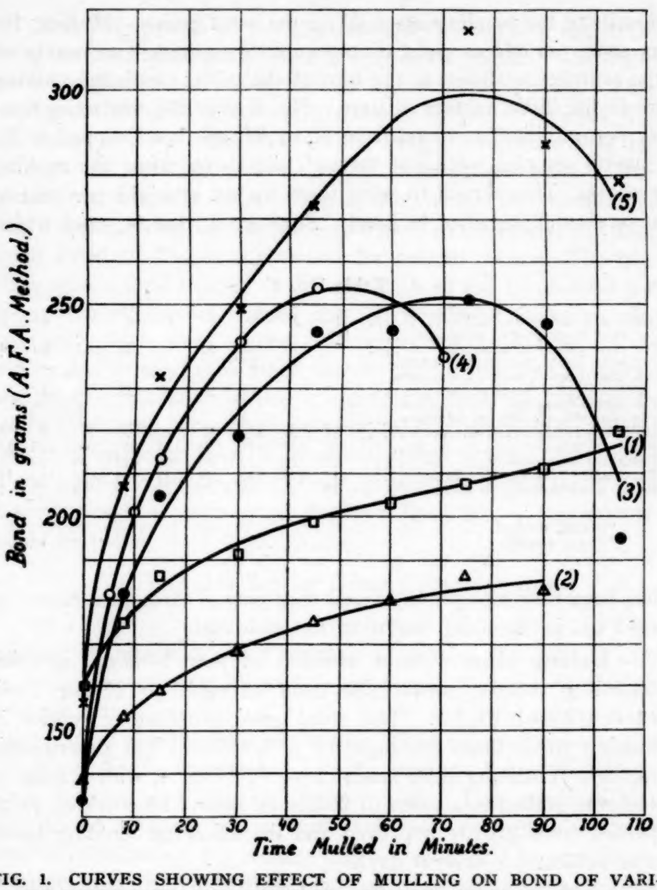

FIG. 1. CURVES SHOWING EFFECT OF MULLING ON BOND OF VARIOUS SANDS AND SAND MIXTURES. NUMBERS REFER TO TABLE 2

mixed thoroughly with the Royer (marked R in the table) or screened (marked S) and then sampled. They were then mulled for various periods and samples were taken after each period.

Maximum bond was obtained only after from 50 to 75 minutes in the machine. These long periods may have been due to the small size of the muller, but nevertheless, they indicate that a very considerable amount of work is required to properly

distribute the bonding material on the sand grains. Mulling for as short periods as eight or ten minutes tightened up nearly all the samples as shown at the foot of the table; continued mulling made but little further change. No. 8 was the one exception; its permeability increased from 30 to 40 and then dropped to 23. Several samples were put through the Royer after the mulling process. This served to open them up six or eight per cent at a very small sacrifice in bond. Such sand, that is, sand which

Table No. 2

Mixture numbers	1	2	3	4	5	6	7	8	9
Per cent heap sand in mixtures	100								
Per cent refuse in mixtures		100	60	60		88	85	80	95
Per cent Local No. 1 in mixtures			30						
Per cent Local No. 2 in mixtures				30	90				
Per cent gallia in mixtures			10	10	10	12	10	10	
Per cent Albany No. 2½ in mixtures							5	10	
Per cent Albany slip in mixtures									5
Method of mixing	S*	S	R**	R	R	R	S	R	S
Bond of mixture	160	139	134	139	156	133	144	133	138
Perm. of mixture	20	28	23	26	45	25	20	30	19
Bond after mulling 10 minutes	178	155	190	198	212	169	158	143	178
Perm. after mulling 10 minutes	19	23	19	21	43	19	19	37	16

*Screen method.
**Royer method.

has been thoroughly mulled and then passed through a Royer or riddle is in excellent condition for molding.

Mulling alone without addition of new bonding material, served to restore considerable bond strength to refuse sand, curve (2) of Fig. 1. This sand gave satisfactory service in making small brass castings for a few heats but deteriorated rapidly. Ordinary heap sand, curve (1) Fig. 1, with a bond of 160 was mulled to a value of 203 in an hour. Its working properties were greatly improved and the effect on molding losses was evident for several days.

Sand mixtures Nos. 3 and 4 (Table 2) were found very satisfactory for rebuilding molding heaps. One or two wheelbarrow loads were added each week; No. 3 if the heap sand was sufficiently open, No. 4 if too tight. If weak in bond and yet tight, more No. 2 sand was used. These mixtures and similar ones containing different proportions of refuse, Gallia and the two local sands have been in regular use, in our foundry, replacing the more expensive Eastern sands with marked success during the past year.

The long period of mulling necessary to develop maximum bond operated against the practicability of the method. Attempts were therefore made to use the mixtures without mulling. They were put through the Royer machine and then introduced into the heaps or else introduced as the entire sand heap was put through the machine. When added in small quantities at frequent intervals, the bond value of the heaps was maintained fairly well so long as they were not used too severely. In fact, fairly good results were obtained for several weeks. The handling of the sand seemed to develop some of the bond—and fast enough to offset that burned out. It developed, however, that mixtures which were mulled maintained and even built up the bond value of the heaps much better. In fact, best and quickest results were obtained on badly burned out floors by putting the entire sand heap through the muller, adding the rebond and refuse sand in the process. It was impractical to leave the batches in the muller long enough to develop maximum bond but five to ten minutes has given good results. Doubtless a longer time would be better.

Effect of Mulling on Other Characteristics

In order to further study the effect of mulling on the physical characteristics and working properties of sand and also to study the relation of certain proposed methods of test to working properties, several of the sands and sand mixtures of Table No. 2 were examined further. The samples were tested according to the standard A. F. A. methods for permeability, bond, fineness and dye absorption value. The same samples were tested for bond by two rapid methods with which we have been experimenting for routine control work and by the Smith vibratory method[5]. The data obtained in two sets of these tests are shown graphically in Figs. 2 and 3. Fig. 2 charts the values obtained on sand mixture No. 3 of Table 2, 60 parts refuse, 30 parts local No. 1 and 10 parts Gallia sand. Fig. 3 shows results on mixture No. 5, 90 parts local No. 2 and 10 parts Gallia. Fig. 4 is a photograph of one of three sets of vibratory tests made on mixture No. 3 and the sands entering into its composition. So far as the relation between the various characteristics is con-

[5] **E. W. Smith, *A Physical Test for Foundry Sands*, Transactions A. F. A., Vol. 31, pp. 623-630.**

cerned, the data recorded in these charts do not differ materially from that obtained on the other sand mixtures.

Line S on each chart represents the bond values as determined by the standard A. F. A. method. The No. 3 mixture was tried out on two molding jobs without mulling. Losses due to dirty castings were heavy and the sand was pronounced "no good." When mixed thoroughly with good heap sand, half and half, it gave fairly good results. The bond value was 152. After mulling No. 3 for eight minutes it was used for difficult molding with marked success; no losses which could be definitely ascribed to the sand were made. After a still longer period of

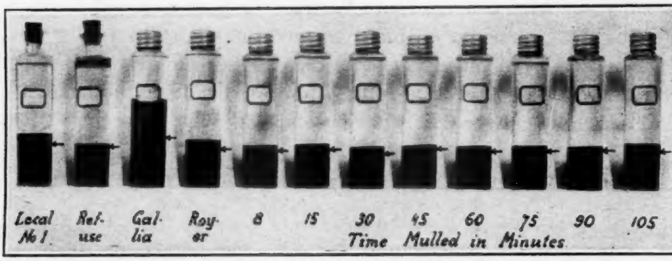

FIG. 4. VIBRATORY TEST ON LOCAL NO. 1, REFUSE AND GALLIA SANDS AND MIXTURE NO. 3, COMPOSED OF 30 PER CENT LOCAL NO. 1, 60 PER CENT REFUSE AND 10 PER CENT GALLIA SANDS

mulling it was used on some of our most difficult jobs with excellent success. Our experience indicates that the standard bond test is closely related to the working properties of the sand and that it measures a property which is one of the determining factors in the production of dirty castings.

Line B represents bond values measured by one of the rapid methods. Test specimens 1 inch x 1 inch x 12 inches in size are rammed up by hand, using only a two part core box and a core maker's mallet and trowel. These are pushed slowly over the edge of a plate or table and the average length of the broken pieces is taken as a measure of bond. This method is very rapid and has been successfully used for core sand control work in our foundry during the past four years and for molding sand work until recently when we replaced it with the tensile method described below.

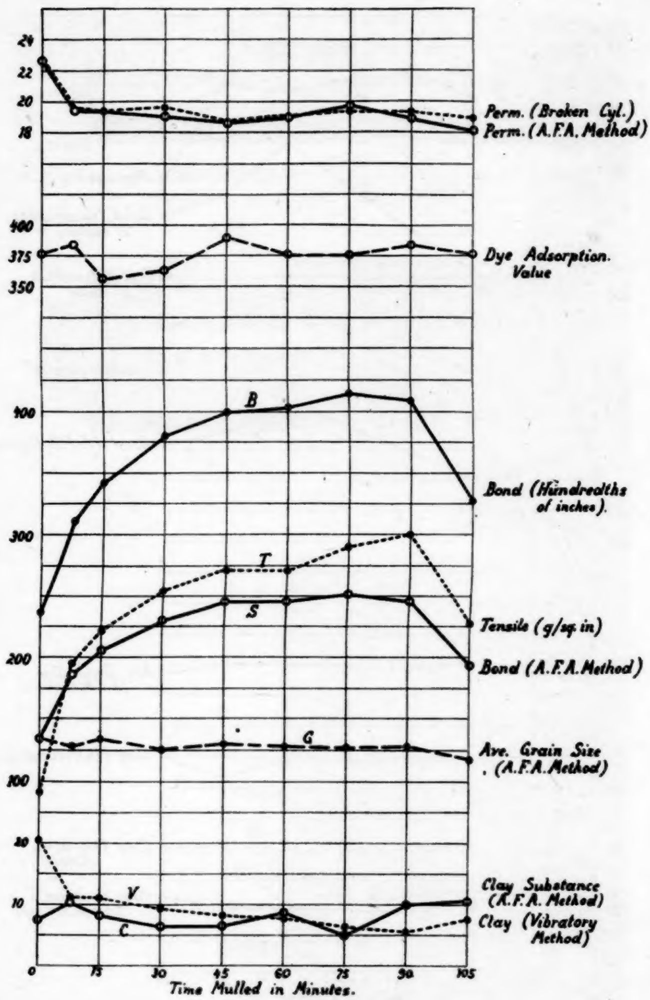

FIG. 2. EFFECT OF MULLING ON THE PHYSICAL CHARACTERISTICS OF SAND MIXTURE NO. 3, COMPOSED OF 30 PER CENT LOCAL NO. 1, 60 PER CENT REFUSE AND 10 PER CENT GALLIA SANDS

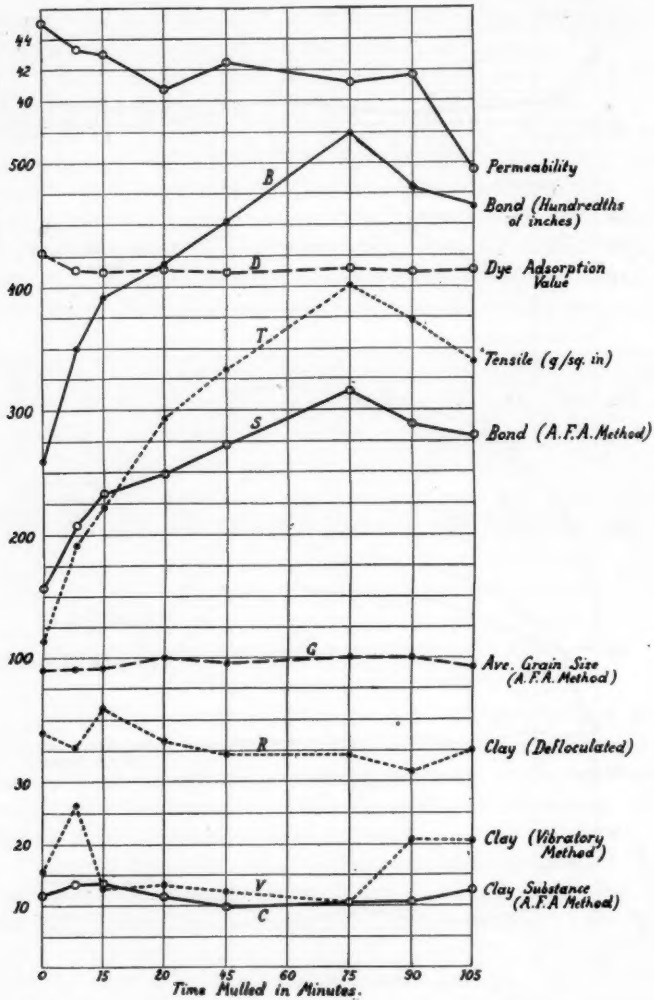

FIG. 3. EFFECT OF MULLING ON THE PHYSICAL CHARACTERISTICS OF NEW SAND MIXTURE NO. 5, COMPOSED OF 90 PER CENT LOCAL NO. 2 AND 10 PER CENT GALLIA SANDS

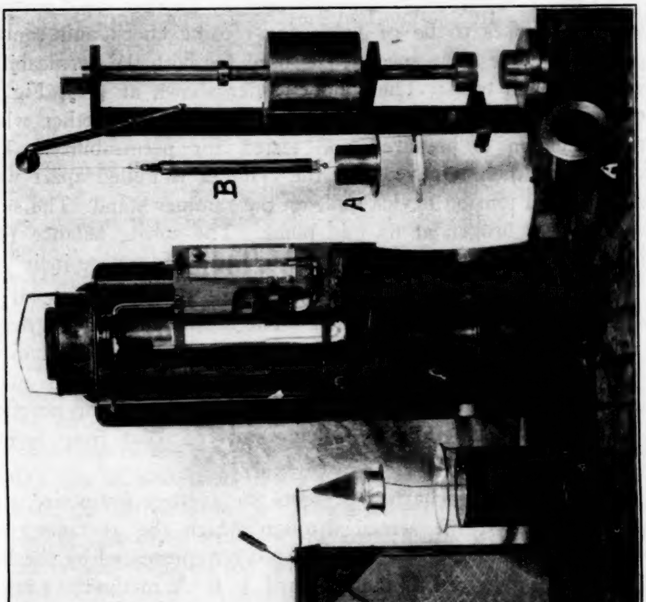

FIG. 5. MOISTURE (LEFT), PERMEABILITY AND TENSILE BOND TESTING APPARATUS USED IN SAND CONTROL WORK

Line T represents values obtained by another rapid method which promises to be of value for routine check and control purposes. The same specimen is used for both the permeability and the bond tests. The sand cylinder shown at (A), Fig. 5, consists of two parts which are firmly clamped together while the specimen is prepared and tested for permeability. The clamps are then removed and the cylinder is pulled apart with the aid of a tension device built on the rammer stand. The sand specimen is broken at its mid point. The spring balance (B) is calibrated to register the tensile strength per square inch.

It is evident that the three methods of test for bond or strength are very closely related. The tensile test shows greater difference in the relative strength of two given samples than do either of the other tests. The permeability determinations made with a two part cylinder are sufficiently accurate for practical purposes even after the parts have suffered wear from several hundred determinations.

Line G in the charts represents the average grain size, that is, the mesh of the screen through which the average grain would just pass after the clay substance, represented by the line C, has been removed by the standard A. F. A. method[6]. Line D shows the dye adsorption values of the samples. In all the tests the grain size and clay content as well as the dye adsorption value remained practically constant throughout the entire period of mulling.

The Smith vibratory test, line V and Fig. 4, gave results which in some cases were comparable with the clay substance obtained by the A. F. A. screen method; in other cases, heap sand and refuse sand (see Table 1), for instance, there were marked differences. The vibratory test usually gave higher values. On sand mixtures No. 5 (chart Fig. 3) the results were rather erratic so the samples were treated with dilute caustic solution, shaken, neutralized with acetic acid and then vibrated and allowed to settle according to the Smith method. The average results are represented by the line R. They are considerably higher than those obtained without the use of a defloculat-

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[6]Tentatively Adopted Methods of Tests of the Joint Committee on Molding Sand Research, American Foundrymen's Association, June, 1924, pp. 54, 55.

ing agent, indicating that the original method probably does not completely break up the aggregates.

Potential Versus Sensible Bond

The data collected thus far by the various investigators point only to general conclusions regarding the relation between average grain size, clay content, dye adsorption value and bond. It is evident that fineness, clay, colloidal matter and moisture determine the strength of sand. There may be other factors. No definite relation has yet been established; the field is a fertile one for investigation. Permit us to offer one thought in this connection.

The fact that by mulling samples of sand we are able to develop greater bond while the other characteristics mentioned above remain constant, indicates that possibly these characteristics determine the *potential* bond, that is, the maximum strength which can be developed in a given sample. The *sensible* bond, that is, the actual strength existing at any given time, is determined by the distribution of the particles as well as their size, quantity and composition and is measurable only by strength tests of some kind. If this is a fact, and there is abundant evidence that it is, then in producing sand or in purchasing it we are interested primarily in the factors which determine potential bond, namely fineness, clay, dye adsorption value and perhaps others. On the other hand, in using it on the molding floor we are interested mainly in the sensible bond—the bond strength actually present.

Molding Sand Control

The successful use of reclaimed sand depends a great deal on knowledge of the sand heaps into which it is introduced and of the work being made in them. Our reclamation work has been done in close conjunction with control work. In fact, control methods were extended to the foundry floors several weeks before attempting to use reclaimed sand in any great quantity. So any success we have had with reclaimed sand was due in part at least to the control methods.

One man devotes full time to sand control and reclamation work. He is held responsible for the condition of the sand

heaps in our brass foundry and makes all additions of sand. Additions are determined by the size of the heap, the bond and permeability of the sand and the type of job being molded, so the man has a real life size job. He works in close conjunction with the floor bosses, or instructors as they are called, each of whom have charge of several molding floors.

In order to facilitate this man's work we have placed specially constructed test apparatus in a room adjacent to the foundry. Each sand heap is tested for bond and permeability and appropriate additions are made at least once a week, sometimes two or three times, depending on the individual jobs. Heavily cored jobs frequently require daily attention.

The test apparatus consists of the standard A. F. A. permeability testing outfit fitted with a direct reading scale for use with the standard orifices, the tensile bond measuring device described above and a moisture measuring apparatus. This equipment is shown in Fig. 5.

The moisture determination apparatus consists of four electric heating chambers arranged to pass dry air at about 400 degrees Fahr. through as many samples of sand contained in small aluminum capsules; also an automatic weighing device equipped with a chart that indicates the percentage moisture without calculation. With this outfit we are able to make from 30 to 40 determinations per hour; a single test in from five to eight minutes.

Foundry Losses

A very important factor in our foundry control work is the system for determining and recording losses. Each molder's castings are kept separate until they have been cut from the gates, cleaned and inspected. Molding losses due to dirt and shifts are charged against the molder's piece rate wage. The instructors may earn a weekly bonus by making low losses. The daily loss of each molder is reported back to the instructor and charts showing the loss of the group under each instructor are posted. The losses on each molding floor are co-ordinated with the physical characteristics of the heaps and the additions of the sand as an aid to the man handling the sand.

The results of a year of control work, the last ten months of which recovered sand was used in considerable quantities on

all our brass molding floors, have been very gratifying. The reclamation work alone has made no great saving because our consumption of sand is not large. It has, however, covered the expense involved in reclamation and control work, giving us the benefits in the way of reduced losses as clear gain.

During the years 1922 and 1923 the cost of the new molding sand used in our brass foundry was slightly over $1.00 for each ton of good castings produced. This was due to the fact that we were using only high grade Eastern sands and paying high freight rates. During the past six months this item has averaged only $0.46 per ton of castings, a reduction of 54 per cent.

The reduction in foundry losses during the past year has been worth much more than the saving in sand. During 1922 our brass foundry loss was 8.5 per cent. It averaged 9 per cent for the first three-quarters of 1923. Since that period there has been a marked reduction, the average loss for the past five months being a little less than 4 per cent. Dirty castings were reduced 60 per cent and blows and mis-runs 55 per cent. Translated into dollars and cents this means a saving of some two or three thousand dollars per month.

This saving is, of course, not due to molding sand alone. We would certainly not ascribe it to the use of recovered refuse sand. The personal factor is such an important element in molding that due credit must be given to the molders and their instructors. The system of recording losses and placing responsibility for them has been a big factor. Greater care in handling the metal and changes in gating have had important bearing. The sand control work, however, which has been carried along with the reclamation work, has been a most important factor in two respects: First, it has helped to keep the sand heaps in good condition and so permit the molder to get better results; and second, it is giving definite knowledge about the condition of the sand so that no longer is the sand "the goat" for every trouble the molder may have, the cause of which is not readily apparent.

Discussion—Molding Sand Reclamation and Control Experiments

A. A. GRUBB: The work I am reporting on today is a continuation of the work undertaken about two years ago under the auspices of the Committee on Conservation and Reclamation. The sand that we are experimenting with is sand shaken off of the castings and sand that collects on the floor which has been going into our dump. About a year ago, or a year and a half ago, we started two molding sand heaps, using nothing but the reclaimed sand, with about 5 to 10 per cent moisture, and operated these heaps for six months, making careful observations on losses due to misruns and dirt before we attempted to put the scheme into practical operation over the whole foundry. A little over a year ago, in October, 1922, we put the plan into operation, and since that time we have discarded no refuse sand, rebonding all, adding only sufficient new sand to make up for that small percentage of sand which gets by that is actually carried out of the foundry with the castings.

F. L. WOLF: I would like to say that we also make a line of valves from one-eighth inch up to three inches, and since this control work has gone into effect, our losses from leakage have been less than 1 per cent; they will average around seven-eighths of one per cent.

DR. H. RIES: I would like to ask Mr. Grubb how the figures obtained for this moisture determination apparatus agree with the figures obtained by the ordinary method? As I understand it, you force hot air through here at a temperature of about 400 degrees Fahr.

A. A. GRUBB: We felt that we were safe in using temperatures up to 400. I would say offhand that the error would be less than two-tenths of one per cent.

CHAIRMAN W. M. SAUNDERS: Then you feel that the investigation on unknown sand for moisture by the moisture apparatus is to be recommended?

A. A. GRUBB: No, sir, I would not recommend it for anything but routine work. I heartily agree with the present A. F. A. method; this rapid method is for control only.

H. W. DIETERT: I would like to ask Mr. Grubb whether he finds that the tensile strengths of sand and iron are related in consistency of readings?

A. A. GRUBB: I am not certain that I can answer Mr. Dietert's question, that is comparing the results for molding sand and iron. I can only say this, that the tensile strength tests are far more sensitive

than a flexure test in the relation which I gave. We are able to check tensile strength tests within 5 per cent as easily as we are to check flexure tests within 10 per cent.

Dr. H. Ries: Do you feel that that tensile strength test would work on all grades of sand?

A. A. Grubb: We have used it on Millville gravel and heavy road sand, southern Ohio No. 4; No. 0 Albany, silica flour, which carries very low colloidal content, and refuse sand. I believe this will give you an idea of the various grades we have tried it on. I might add that the compression test surprised me greatly by giving almost the same relation on sand as did the tensile test. Further work will be necessary to see that that relation is correct, but if it is we are very fortunate.

E. W. Smith: If I understand Mr. Grubb, I believe the entire paper was applied to his brass foundry, am I right?

A. A. Grubb: You are right.

E. W. Smith: I consider the last two papers the two most able papers I ever read. I happen to be fortunate enough to have had an advance copy. I went through that paper and read it from the one end to the other and remarked little items here and there. There is one little evil I would like to have Mr. Grubb go into a little more thoroughly, and that is in his use of vibratory tests. There is a common error that occurs, I have seen it cropping out here and there and everywhere, that in the bonds the fines do not separate. Invariably you will find that condition occur when you are trying to separate an extremely fine material. When you use the vibration on heavy sand in making that test, you are simply assisting gravity; only assisting the laws of nature by bringing those heavy materials down. When you go into extremely fine materials, such as fine silica, if there are three divisions of that material, they should show that each operation has been done properly. I have had sand divide into three and four parts in the vibratory test. I gave it to the foundryman for what it was worth just as a yard stick, as I said a year ago. I have tested probably 10,000 specimens of sand and that is a very low figure—not personally but through my own help. I have found that we have been able to control them by the vibratory test without any other form of test, within 4 per cent either way, in a knowledge of your bond in your sand in the foundry. Further than that, I have been able to reduce the losses. I am glad to hear of the effect of the tests made in Mr. Grubb's foundry in the Ohio Brass Company. I should say that they have been able to accomplish the same as I have, an extremely great reduction in loss; that is, in other words, in the vicinity of three per cent for a matter of two or three years. I have the records of over a year and a half that I will show to anybody who cares to see them, showing that there was very seldom a variation of 4 per cent higher in the bond of the sand in use.

We are coming down to earth. Dr. Moldenke stated that what we want is something every foundryman can use, what we need is something simple, easily applied, something that the average foundryman can do. In your paper you call men instructors. Why don't you give them the name that is coming to them, assistant foremen? They are your future foremen; they are assistants; they are the men who are following up and are put in entire charge of that work. It is quite interesting to all of us and if you go back into your own foundries and take up this sand question, some of you will come back here and do as Mr. Grubb has done and as has the other gentleman who read a paper. They are all working for one common interest. The American Foundrymen's Association has gone into all the details from the academic point of view. Some of them, as I feel Mr. Grubb and Mr. Wolf have done, have gone into it from the foundryman's point of view. What we need is something to reduce that enormous foundry loss in the United States, which is something awful. Sixty per cent of all the scrap you make in a day you can safely say is due to either the improper use of sand or the use of an improper sand, and I say let us come here next year ready to discuss again a few more able papers like those presented today, and it will do a lot of good in the foundry business.

A New Method of Measuring the Hardness of Molds

By E. Ronceray, Paris, France

At the first International Foundry Exhibition, which took place in Paris in September, 1923, the author exhibited a small mold hardness meter that he designed in view of studying systematically the methods of mold ramming actually in use. This study is not yet completed, so the author did not think very useful to publish description of the meter. However, on the insistent demand of H. Cole Estep, who saw the apparatus at the last Birmingham Foundry Exhibition, and on the insistence of E. Ramas, President of the French Association, he finally wrote this

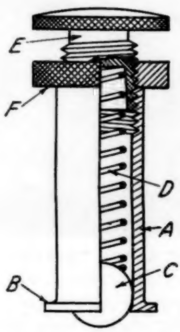


FIG. 1—MOLD SURFACE HARDNESS TESTER

short notice expecting that it will be helpful to foundrymen at large.

This apparatus is based on the principle of Brinell ball hardness tester. It is composed (Fig. 1) of a small cylindrical brass piece (A) bored to a diameter of 15 millimeters terminated by a flange (B), 25 millimeters in diameter. At the end of the hole is a bevel circular stop to retain the ball (C) inside the tube,

though allowing it to project outside of it. The ball is pushed out by a spring (D), the pressure of which is adjusted through a screw (E) screwed on the brass piece so as to give a pressure of one kilogram on the ball. A lock nut (F) is provided to avoid unexpected disadjustment. The pressure is measured by pressing with the apparatus on a scale or a similar process.

By placing the apparatus on a mold and applying sufficient

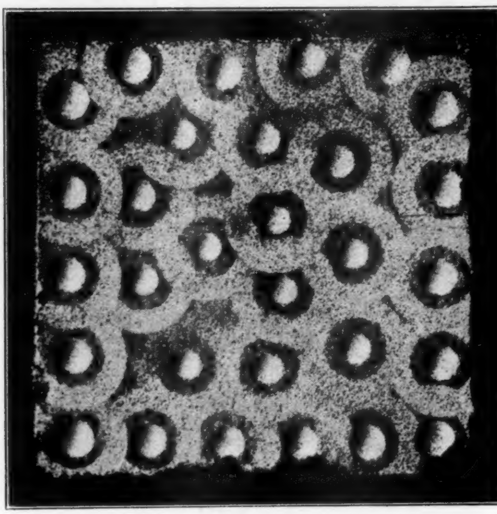
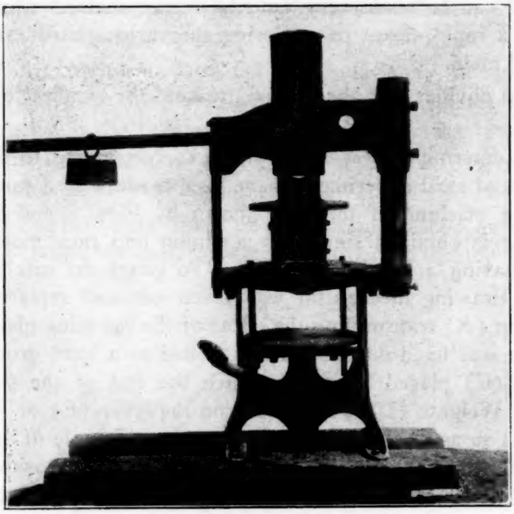


FIG. 2—MOLD SURFACE TESTED FOR HARDNESS

pressure to bring the flange in contact with the sand of a rammed mold, the ball is pressed on this surface by the spring with a force of one kilogram and the diameter of the ball print varies according to the density or hardness of sand. To make the reading easier, it is advisable to spread French chalk on the mold and to blow it off when pressure has been applied. The chalk is pressed on the sand by the ball and the flange with the result that, after using a blower, a white circle appears surrounded by a white ring. The appearance of a block of sand with prints obtained by this process is shown by Fig. 2. A large number of



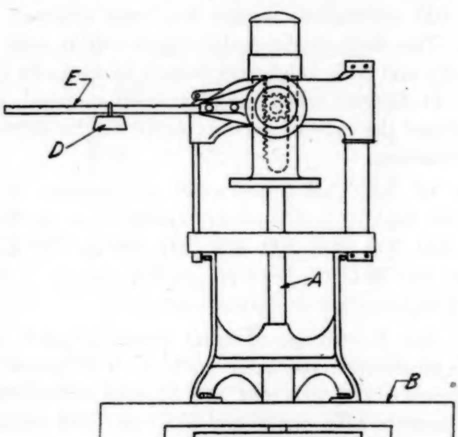


FIG. 3 (UPPER), FIG. 4 (LOWER)—SQUEEZER MACHINE RIGGED FOR MOLD HARDNESS TESTS

readings can be made very quickly by this method which constitutes a rapid means of exploring the various hardnesses of a rammed mold.

It is obvious that the harder the sand the smaller the round print.

To determine the size of prints corresponding to different densities of sand experiments have been made with a small hand ramming machine of the type shown by Figs. 3 and 4. The ramming is obtained simply by a pinion and rack motion, the pinion having a lever bolted to it. To gauge the machine, the pattern drawing mechanism was taken out and replaced by a stanchion (A) transmitting the effort of the ramming plate. The machine was fixed on timbers (B) bolted to a solid ground and a scale (C) placed below on which the end of the stanchion rested. Weights (D) were placed on the lever (E) at different positions so as to obtain total pressures on the scale of 100, 150, 200, 300, 400, 500, 600 and 700 kilograms. The positions and values of such weights were marked so that by simply repeating them, a known pressure was exerted on the ramming plate.

A flask 100 millimeters square has been selected for the experiments. This flask is shown by Fig. 5. It is split along a diagonal (A-B) and both halves are joined by eyebolts (C) and cotters (D). If desired, when sand has been rammed, the flask can be opened and the cake of sand explored on the sides as well as on top and bottom.

The size of flask being 100 x 100 millimeters or 10 x 10 centimeters, the surface is 100 square centimeters, so that when pressures of 100, 150, 200, 300, 400, 500, 600 or 700 kilograms are applied on this flask the pressure on the sand is 1, 1½, 2, 3, 4, 5, 6 or 7 kilograms per square centimeter.

To get a fair knowledge of what happens under different conditions, experiments have been made with different degrees of moisture from 4 to 8 per cent and various thicknesses from 25 to 100 millimeters after ramming. Four per cent moisture has been found to correspond to very dry sand and 8 per cent to very moist.

Experiments are in progress to study by the use of the apparatus described various systems of ramming: Squeezing by

ordinary methods, squeezing with down sand frame, jolt ramming, hand ramming, pneumatic rammer ramming, etc.

These experiments are not yet sufficiently advanced to justify a complete discussion here, but it will be interesting to examine what is the relation between the unit pressure on sand and size of ball print and what is the influence of different degrees of moisture between practical limits mentioned above.

With the ordinary form of sand frame placed on the top of box, it is known that the sand is harder at the top than at

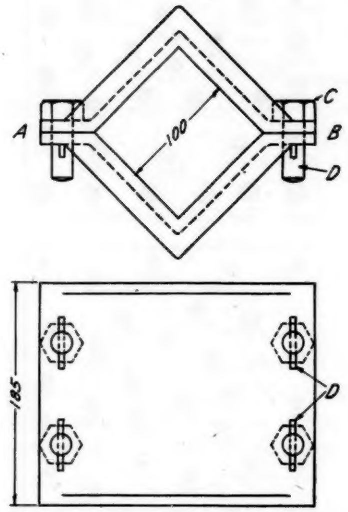


FIG. 5—SPECIAL FLASK USED IN HARDNESS TESTS

the bottom. Fancy curves have been printed in this respect. Fig. 6 shows the readings taken on both sides of a cake of sand for different thicknesses and different pressures. If the edges are not taken into account, the *diameters of prints have been found independent of sand thicknesses* within the limits of experiments.

It also shows the interesting fact that between top and bottom, the differences of pressure corresponding to ball prints

average are rather small and comprise between 3.70 and 7 per cent.

A large number of experiments have been made on sand with various thicknesses, dampnesses and pressures, which cannot be all reproduced here.

A typical sample is given in Fig. 7 for a content of 6 per

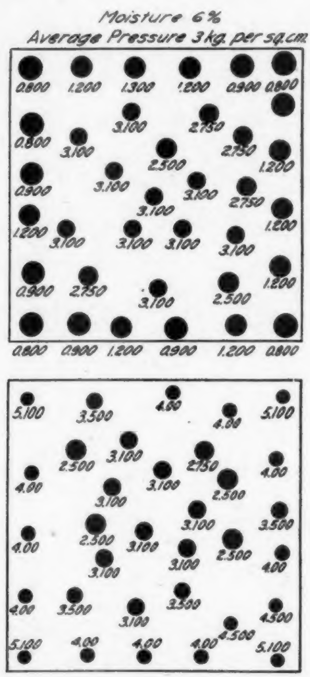


FIG. 6—SHOWING READINGS TAKEN ON BOTH SIDES OF A BLOCK OF SAND

cent of water and a pressure of 3 kilograms per square centimeter which are about common practice.

It is convenient for measuring the size of prints to have a magnifying glass or a small microscope.

This very simple apparatus can be handled by anybody and be used constantly in the foundry with a little experience. It is

hardly necessary to measure the prints. The naked eye is almost sufficient to detect the weak points of wrong ramming.

The author is sorry not to be able to give more complete results. He would have preferred to wait until he has completed his experiments to publish anything. However, he has

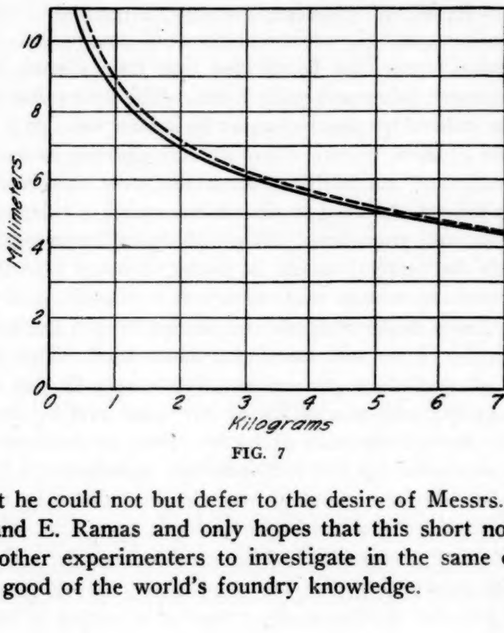


FIG. 7

felt that he could not but defer to the desire of Messrs. H. Cole Estep and E. Ramas and only hopes that this short notice will induce other experimenters to investigate in the same direction for the good of the world's foundry knowledge.

Commercial Application of Molding Sand Testing

By H. W. Dietert, Detroit, Michigan

Foundry losses may be divided into four classes, namely, iron, equipment, labor and sand losses. The losses due to sand, directly or indirectly, may be largest in some cases. It is always one of the greatest factors when we consider the losses caused both directly and indirectly by unsuitable sand conditions. All the above named classified losses are increased to a large extent by adverse sand conditions. When the sand is correctly tempered with the correct amount of water so as to give the sand it's best working texture and maximum permeability or venting quality, a much duller iron may be poured than if the sand was either too dry or too wet, causing a dense sand. This physical property of maximum permeability for a specific job may be obtained by the proper addition of new sand and by tempering sand with the right amount of water. Both of these properties are best controlled by test methods later described.

The loss due to equipment may also be reduced by using an adaptable sand. An adaptable sand for a particular job would be one possessing properties which would allow for deformation and strain produced by the nature or quality of equipment.

The loss due to labor is also remarkably related to sand conditions. Suppose the molder finds his sand to be too dry or too wet, either of which will produce a dense and weak sand of poor working texture. The molder is immediately discouraged and counts on a bad day's work. This psychological effect will undoubtedly be indicated in the day's loss.

Sand Conditions Control Important

The problem then is how to get good sand conditions each day which are exactly adapted for the job. Sand control testing will partly answer the question by its application to the daily foun-

dry practice. This enables the foundrymen to get numerical figures which will express exactly the physical properties of the sand used, or to be used. The physical properties which are determined for control work are permeability, strength, and moisture. The fineness test is a very valuable addition to this list.

The following are the values found to be desirable for boiler molding sand: permeability 35 to 45, compressive strength 2 to 3¼ pounds, and moisture, 7 to 8 per cent. These physical properties are kept within the working range by the proper addition of adaptable new sand as open sand, or bonding sand, and by correct tempering.

The figures obtained from sand control testing are of no value unless the foundryman will apply and study them by correlating them daily with his losses. Following this practice, the range of permissible variation of physical properties of his heap sand that will give him the best results in practice is soon determined. After this range is once determined, it is a fairly easy task to keep his sand within the chosen limits.

Should the foundryman keep his sand just so open, so strong and mixed properly with the correct amount of water to produce a good tempered sand, it is quite evident that the loss will be materially reduced.

Test Methods Used

Permeability:—The permeability of the molding sand is determined by the use of the A. F. A. standard permeability apparatus. The procedure of test method used in the laboratory is in accordance with the A. F. A. methods.

Fineness:—The fineness test is also in accordance with the A. F. A. test method with the following exception: a 300 gram sample of sand is used in place of the 50 gram sample. This is done in order that sufficient amount of sand grains are obtained, after the clay substance is removed, to make a standard permeability test specimen from the sand grains. The permeability of the sand grains is called the base permeability.

Heat Test:—The procedure of the heat test or durability test is to heat a sample of the sand in a furnace to 600 degrees

Fahr. for a period of two hours. The loss in strength and permeability change is expressed in percentage. This test is used to give the life of new sands submitted.

Strength or Bond:—The cohesiveness of the sand is determined by a compression test. The word strength is used in place of the word cohesiveness, for the word strength conveys a definite meaning due to its universal use in material testing. The strength of molding sand is expressed in pounds per square inch, which is both conventional and simple.

Description of Compression Test Method

The strength test is made by filling a cylindrical mold 1⅛ inches in diameter (A Fig. 1) with the sand to be tested. The mold containing the sand is then placed under the rammer (B Fig. 1). A stop pin is next removed from the bottom supporting post of the mold. The sand in the mold is rammed by raising the weight (C Fig. 1) to the top stop (D Fig. 1) and letting it fall from this position. Since the mold is free to move on

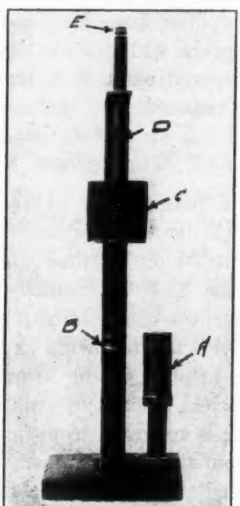


FIG. 1—THE RAMMING MACHINE USED TO RAM THE COMPRESSION TEST SPECIMEN

the bottom supporting post, the sand specimen is rammed from both ends, producing a very uniform rammed specimen.

The top of the ramming rod should be within the two tolerance marks (E Fig. 1) in order to give a test specimen whose length is from 1.75 to 2.00 inches. Specimens within this range of length are of both theoretical and practical length to give true compressive strength and consistent values with diameter of 1⅛ inches.

The lengths of the rammed specimens are easily obtained by the aid of placing the stop pin of the supporting post of the

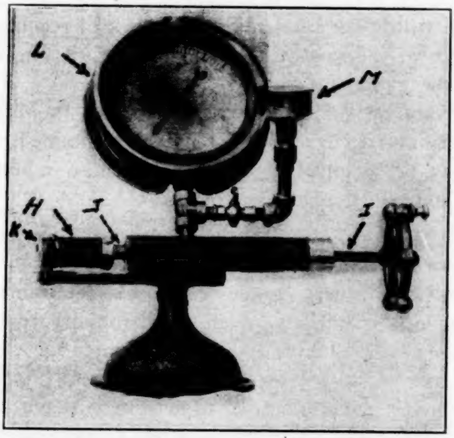


FIG. 2—THE COMPRESSION TEST MACHINE WITH SAND TEST SPECIMEN IN TEST POSITION

mold in one of the various holes, so that the amount of sand which the mold will hold is gauged.

The test specimens are removed from the mold by stripping the mold over the supporting post. This operation will cause the test specimen to be stripped free from the mold. The test specimen (H Fig. 2) is then picked up by hand and placed in the testing machine as shown in Fig. 2.

The test machine (Fig. 2) consists of a screw plunger I which upon turning creates an oil pressure on the oil floating piston J. At the head of this piston J, and at the end rest K,

are mounted ball socketed bearing plates to equalize load application on the test specimen. The oil pressure on the piston J, or that which is supported by the sand specimen, is indicated by the gauge L in pounds per square inch strength of the sand. The cup M is used to replenish the oil supply in the system.

The procedure of the test after the specimen is placed in the test machine is as follows: The hand wheel of the screw plunger I is turned by hand at the rate of 40 R. P. M. Consistent test readings are easily obtained by this hand operation. As the hand wheel is turned the oil pressure will increase, producing an increasing load upon the sand test specimen. The specimen of sand will break suddenly when the load reaches the ultimate strength of the sand. The operator records the maximum reading of the gauge L.

The advantages of this strength test are rapidity of test, and simplicity and accuracy of test readings obtained. Strength readings may be obtained at the rate of one a minute with a very small amount of manual effort.

Moisture Test Method

The moisture in new samples of sand is determined by drying the sample of sand in an oven. For foundry control work, this method is very slow and the small sample of sand used is not always representative of the heap sand.

A volumetric method is used to determine the moisture control in the heap sand. This method gives moisture percentage in approximately two minutes' time and employs a 860 gram sample of sand (double hand full).

The apparatus used in this volumetric moisture determination is shown in Fig. 3. It consists of a cylindrical flask having a side outlet B. This outlet B is located directly above the glass tube C. Along the side of this tube is attached a scale reading in percentages of moisture. The glass tube C contains, on its lower end, a bulb and a stop cock. It may be noted that in Fig. 3, three moisture tubes are assembled on a common base. The number of tubes used is governed by the number of samples it is desired to test at one time.

A moisture determination is made by placing the 860 gram

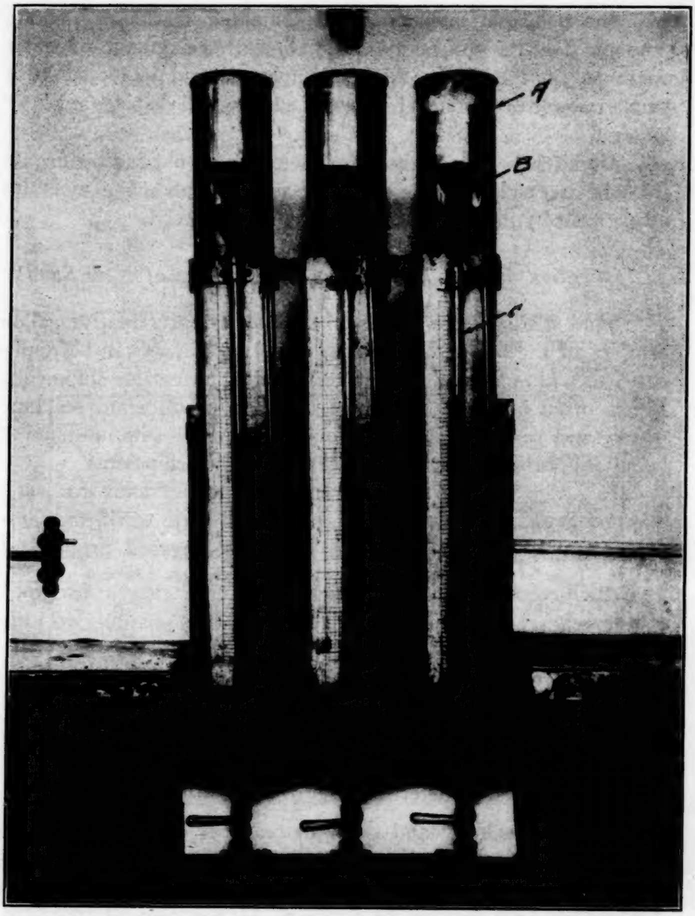


FIG. 3—THE VOLUMETRIC MOISTURE DETERMINATION APPARATUS

sample of sand in the top flask A, which has been previously filled with water. The water displaced by the sample of sand is caught in the glass tube assembly C. The height of water column in the tube C, resulting from this overflow of water, gives the moisture reading.

The principle involved in this method is that a definite amount of water will be displaced for each percentage of water contained in the sand. A dry sample of sand will displace a small amount of water, while a wet sample will displace a larger amount.

Employing this method for determination of moisture in sand heaps, will give the operator a chance to make moisture adjustment of the sand, if necessary, immediately.

Application of Test Methods in the Selection of New Sand

Sand salesmen are requested to submit representative gallon samples of the prospective sands, which he knows can be duplicated to within 20 per cent of test reading in car-lot shipments. It has often been the custom of the sand producer to see how many sand samples he really could find in his pits, and never being able or intending to duplicate in car-lot shipments.

In order to determine the most adaptable sands for each class of work, such as radiation, boiler and plate work, the sample furnished is tested for the following physical properties:

1. The determination of permeability and strength for each percentage of moisture variation over the possible working range.
2. The percentage of clay contained.
3. The fineness of sand grains.
4. The base permeability of sand grains.
5. Test for lime.
6. The heat test, a determination of the life of the sand.

The permeability and strength readings are plotted versus moisture as shown in Fig. 4. These characteristic curves show that the maximum permeability 20 cc. and maximum strength 4.8 pounds both happen to occur at 11 per cent of moisture. The curve also shows that this sand is not greatly affected by moisture variation. It takes a change of 3½ per cent of moisture variation to make a change of 2½ cc. in permeability. Thus, this sand is spoken of as possessing a moisture working range of 3½. Some sands require a variation of 7 per cent of moisture to change permeability 2½ cc. These sands are very

easily tempered. Sands having a moisture working range of less than 1½ are difficult to temper correctly in the heap.

The results of all the other tests are tabulated on the same sheet with strength and permeability curves as shown in Fig. 4. It may be noted that the percentage of bond as determined by vibratory test is approximately the sum of the percentage of clay and sand grains retained on the screens No. 270 and pan (—270).

Base Permeability

The base permeability of the sand grains is determined after the clay substance is removed. The clean sand grains are rammed in the permeability specimen retainer and held in place

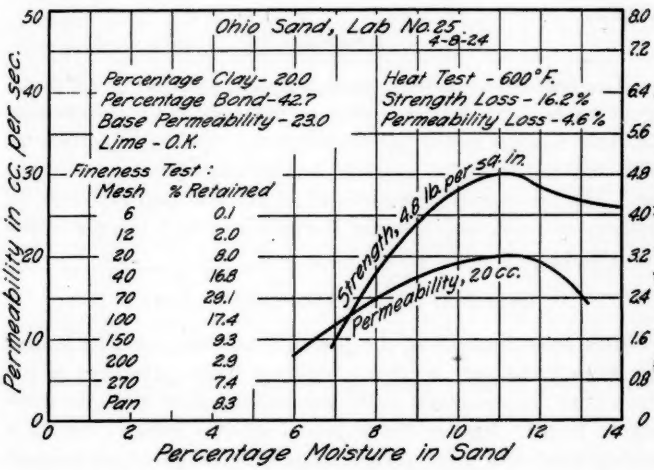


FIG. 4—CHARACTERISTIC DATA THAT ARE USED IN NEW MOLDING SAND FILE

by means of No. 70 screens on each end. The permeability reading will indicate the openness of the sand grain structure. Some sands have a grain size distribution which forms a dense structure, while others have sand grain sizes so distributed which pack into an open structure. A large amount of 270 or pan material will form dense grain structure.

The base permeability is of utmost importance, for it compares the permeability of all sands under like conditions. Some high clay sands are dense due to the amount of clay they contain. If natural permeability is the only consideration given, we would class these sands as closing-up sands for heap sand, while in reality they may have a very open grain structure which would be shown in base permeability reading. When the clay content of this sand is reduced by mixing it into the heap, its open grain structure would act as an opener. All new sand placed in a heap sand will be brought to some predetermined clay content by sand control. In order to determine what the various new sands will do to a heap sand, they should be tested for permeability under a like condition, called the base permeability.

Fineness

The fineness of molding sand is indeed valuable in the grading of sands as to their coarseness. The sand grain distribution and their relation to the permeability and casting properties, as finish and resistance to washing, should also receive consideration. The amount of fine material as 270 and pan indicates its tendency to wash, and also the strength at which the particular sand should be worked in the heap.

Heat Test to Determine Life of Sand

The determination of the life of a molding sand by a heat test seems to be very reliable. Molding sands have been tested which have lost as much as 87 per cent of their strength upon heating to 600 degrees for a period of two hours. Surely a molding sand that loses such a large percentage of its original strength would quickly lose its strength or bond in the heap. Several sands have shown exceedingly low strength loss upon heating, while a few have actually suffered no loss in strength, indicating a very durable sand.

In Fig. 4 it may be noted that the Sand Lab. No. 25 lost 16.2 per cent of its strength and lost 4.6 per cent in permeability in the heat test. This sand is classed as a durable sand. It may be stated that all sands do not lose in permeability in the heat test, for a large number gain permeability.

SAND ANALYSIS COMPARISON

SAND Woden

SHIPPERS C.C. Hatch DATE 5-9-24

SHIPPING POINT Vandalia, N.Y. PLANT Dunkirk

CAR NO. N.Y.C. 6422 TESTED BY [illegible]

CHARACTERISTIC	ANALYSIS		REMARKS
	SAMPLE	CARLOAD	
Permeability-Moisture	21.0 @ 9½%	22.5 @ 9½%	
Strength-Moisture	3.0 lb @ 9½%	3.4 lb @ 9½%	
Percentage Bond	41	39	
Base Permeability	20	22	
Percentage Clay	9.7	9.6	
Lime	✓	✓	
Heat Test, deg. F.			
Strength Loss	20.0 %	20.7 %	
Permeability Gain	52 %	55 %	
Fineness Test :—			
6	——	——	
12	——	——	
20	0.5	0.2	
40	2.2	0.6	
70	12.7	14.9	
100	24.9	39.7	
150	26.8	22.0	
200	9.0	6.7	
270	15.0	9.5	
Pan	11.5	11.8	

FIG. 5—SAND ANALYSIS COMPARISON SHEET USED IN CAR-LOT SHIPMENT OF MOLDING SAND

The Application of Test Methods to Checking Car-lot Shipments

Each car of sand received is sampled and tested for strength and permeability to insure receiving the specific type of sand ordered, and to check the uniformity of sand received. These test values are filed and form a valuable reference.

The method used to check car-lot shipments is as follows: An average sample of the sand is obtained. Dry sample in oven, and, after cooling, add an amount of water which will give the sample of sand the same moisture percentage as that

shown by characteristic curve to give temper. For example, for the checking of a car-lot of sand supposed to be the same as Sand Lab. No. 25, Fig. 4, add 11 per cent water. Mix sample well and test sample for permeability and strength. The strength and permeability should be respectively 4.8 and 20. Shipments are easily met at 15 per cent variation. Cars are rejected when properties vary more than 20 per cent.

When the strength and permeability reading come close to those of the original sample, it is safe to state that the percentage of clay and fineness check very closely. For this reason it is sufficient to make only the permeability and strength test of cars received. However, for cars rejected, and for a more complete check, a complete comparison analysis may be made. A copy of the Sand Analysis Comparison Sheet is shown in Fig. 5. It may be noted that the car-lot shipment agrees very closely with sample furnished of this sand.

The rejection of sand has been largely eliminated by a better understanding on part of the sand producer of the sand desired and his good will to meet definite requirements.

Vibratory Test

The vibratory test was made in conjunction with the permeability and strength tests for over a period of three months in order to determine the merits of each test. The conclusion which may be drawn from the comparison of the test data obtained will be discussed in the following paragraphs.

In the analysis of new sands, it was found that sands containing a large portion of fine material, as 270 and pan material, always showed a higher percentage of bond in proportion to actual strength. Nearly all sand showed a larger amount of bond by vibratory test than the actual amount of clay substance. A part of the bond measured in the vibratory test is pan material.

Samples of a Zanesville sand were heated to various temperatures ranging from air dried to 1900 degrees Fahr. The strength, permeability, and percentage of bond by vibratory test were determined for each sample after being cooled and tempered.

The result of this test is shown graphically in Fig. 6. It

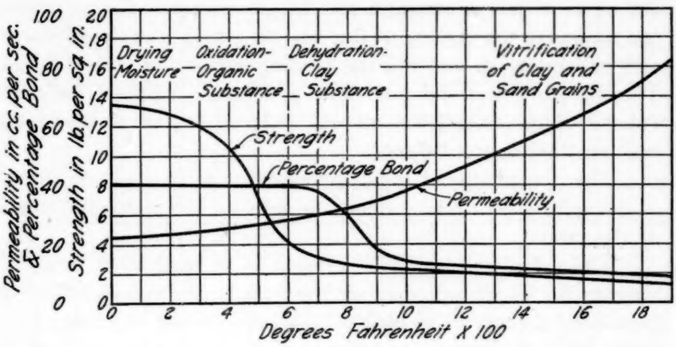


FIG. 6—THE EFFECT OF HEAT ON ZANESVILLE SAND LAB. NO. 7

may be noted that the permeability of the sand increased rapidly after the sand samples were heated beyond 212 degrees Fahr.

The strength loss due to heating sand up to 212 degrees Fahr. was 0.8 pounds. A very rapid decrease in strength was found after sand was heated from 212 degrees Fahr. up to 700 degrees Fahr. After a temperature of 700 degrees, the strength decreased slowly.

The percentage of bond remained very constant until 700 degrees Fahr. was reached. From 700 to 1000 degrees Fahr. a marked decrease in percentage of bond was noted.

Table No. 1.

Comparison Between Percentage Loss of Strength and Bond.

Degrees Fahr. Heat	Percentage Loss in Strength	Percentage Loss in Bond
212	0.59	0.0
300	1.09	0.0
700	78.0	5.0
1000	85.5	62.5
1900	92.5	80.3

A comparison of the strength and percentage of bond curve in Fig. 6 shows that the vibratory test does not always show active bonding material or cohesiveness. The tabulation of strength and bond losses in percentage for various degrees of heat in Table No. 1 show that the bond loss in percentage does

not agree with the strength loss in percentage. The vibratory test measures the volume of fine material, such as clay substance and pan material, and not the binding quality of this material. The vibratory test did not show a decrease in bond until the volume of the so-called bond was reduced by the action of the heat at 1000 degrees Fahr.

The percentage of bond cannot be used in the comparison of a varied class of new sands, to indicate the relative strength of the sands.

The vibratory test does present each sand in a beautiful manner for visual examination from which the foundryman can get a helpful general knowledge. This should lead him to desire to know definitely in numerical values each physical property of the sand, such as strength, permeability, fineness and others.

The vibratory test, when applied to daily sand control of heap sand, offers a much improved method over the old grab guess method. However, the more detailed test of the A. F. A. offers a method which is a step ahead of the vibratory method.

It is unfortunate that the vibratory method was not introduced some time ago because it is a splendid introduction of the more detailed A. F. A. methods which give, definitely, the permeability, cohesiveness, fineness, and so on.

In our control work, it was found that the permeability and strength tests could be made much quicker and, with less calculation than the vibratory test. The dividing line between the bond and grain material in the vibratory test does not show very clearly in burnt sand.

The readings from day to day of the bond were not as consistent as the strength and permeability readings. This is clearly shown in Fig. 7.

The task to make a vibratory test on a large number of floors may be classed as a tremendous job when compared to the ease and neatness of permeability and strength tests.

The strength, permeability and percentage of bond curves are shown in Fig. 7 for No. 3 boiler floor during the month of March. These curves are representative of a mass of similar curves for various floors at different times of the year.

The strength and permeability curves in Fig. 7 are related to a marked degree. For example, an increase in strength is

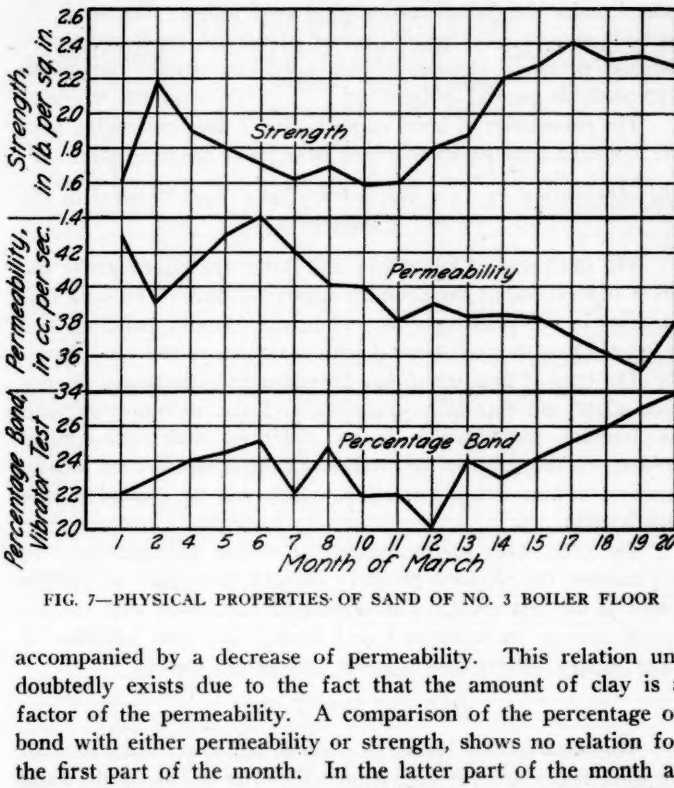


FIG. 7—PHYSICAL PROPERTIES OF SAND OF NO. 3 BOILER FLOOR

accompanied by a decrease of permeability. This relation undoubtedly exists due to the fact that the amount of clay is a factor of the permeability. A comparison of the percentage of bond with either permeability or strength, shows no relation for the first part of the month. In the latter part of the month as the strength increased and permeability decreased, the bond had an upward trend. As a rule a marked increase in strength was accompanied by an increase of percentage of bond, when averaged over a long period of time.

The relative strength or permeability of various floors did not compare with the percentage of bond as obtained from the vibratory test, due to the larger amount of dirt and fine material in certain floors. The grain size is also to be considered as a factor of strength. This property cannot be taken into account definitely by the vibratory test.

The vibratory test may be used to an advantage in sand

control under the direction of a good sand judge. The A. F. A. methods may be used to still greater advantage, for it gives each physical property separately and definitely, while the other method is a general estimation.

The percentage of bond curve in Fig. 7 does not enable anyone to estimate the permeability or strength of the heap sand.

The Application of Test Method to Daily Sand Control in the Foundry

The sand control laboratory and tester are placed under the direct supervision of the foundry superintendent. The sand laboratories in our plants are located in the foundry building, and so located that they are central with reference to the sand floors.

The type of man which has proven most satisfactory to conduct, adapt and appreciate the tests, and also to cooperate with the foundry organization, is an ambitious and open-minded molder. In this manner the products of the laboratory are wholly practical and needed information, which will be applied by the foundryman.

The sand floors are designated by section and numbers. In this manner the physical property of each floor may be quickly found in the test sheet. The doping of each floor with the required amount of new sand and facing, and also addition of water, is specified by floor number and section system.

Duties of Sand Tester

The sand control testing is done at night, at which time all the sand floors are cut and tempered. The duties of the sand tester are:

1. Check temper of each sand floor by the volumetric moisture determination apparatus immediately after the floor is cut.
2. Cooperate with tempering gang to correct any floor in which the moisture variation exceeds the specified limits.
3. Determine the permeability and strength of each floor.
4. Record the test data.

The sand tester performs his duties by obtaining three representative samples from each floor, respectively from front, center

SAND CONTROL TEST SHEET

PLANT Detroit SECTION Radiator DATE 6-24-24

FLOOR NO.	PERMEABILITY	STRENGTH LB. PER SQ. IN.	BOND PER CENT	MOISTURE PER CENT FRONT	CENTER	END	REMARKS
1	23.5	2.70					
2	23.5	2.75		6.2	6.7	7.0	
3	22.0	2.50		6.3	6.5	6.5	
4	24.0	2.50		6.1	6.7	6.4	
5	25.0	2.75		6.1	6.4	6.4	
6	21.5	2.70		6.4	6.9	6.3	
7	20.0	2.90		7.0	6.4	7.0	
8	23.0	3.00		6.7	6.2	6.9	
9	20.0	3.10		6.4	6.9	6.4	
10	20.0	3.25		7.0	7.3	7.1	
11	18.0	3.25		7.2	7.0	7.1	
12	21.5	2.50		6.9	7.0	7.1	
13	22.0	2.75		7.1	7.2	7.2	
14	21.5	2.90		6.7	6.5	6.9	
15	24.0	3.15		6.4	6.4	6.3	
16	28.0	2.75		6.0	6.1	6.2	
21	27.5	2.75		6.7	6.9	6.5	
22	29.0	3.00		6.1	6.1	6.0	
23	25.0	3.00		6.0	6.9	6.2	
24	25.0	3.00		6.1	6.1	6.2	
25	23.0	2.75		6.7	6.1	6.4	
26	27.0	2.75		6.1	6.3	6.7	
27	25.0	2.60		6.4	5.7	6.0	

FIG. 8—SAND CONTROL TEST SHEET, SHOWING THE PERMEABILITY, STRENGTH AND MOISTURE OF RADIATOR SECTION, DETROIT PLANT

and end sections of the floor. The sand samples are screened and the moisture determination is then made of each sample to check the temper of the front, center and end sections of the heap. For those floors where the sand must be worked with a small moisture variation, a moisture range of one per cent is allowed.

The sand control sheet of the radiator section of the Detroit

Plant is shown in Fig. 8. The moisture range for this particular sand is from 6 to 7 per cent. Floors are rejected unless moisture is within this range. Weather conditions are accounted for by working sand closer to 7 per cent on dry days and closer to 6 per cent on wet days.

The remaining portions of the three samples of sand from each floor are mixed together to obtain the permeability and strength values of the particular floor. One sand tester is able to check moisture, obtain permeability and strength values of 50 or more floors in nine hours.

The sand control sheet, Fig. 8, showing the physical condition of each floor, is available at the beginning of each day. A dope sheet is made out showing the amount of new sand and facing to add to each floor to keep it within the strength and permeability limits. These limitations are obtained by noting what strength and permeability gives the best results. The thing that remains for the foundryman to do is to maintain the floors at the desired readings. The physical properties of a sand heap change gradually, which makes it possible to readily correct the change before any serious condition arises.

Benefits Derived from Sand Control Testing

The benefit derived from sand control testing will be illustrated graphically by showing reduction of losses by its application and relation of test readings to specific losses.

When the tests were first applied to the boiler floors, it was found that the sand was not as open as suspected. The sand was opened up and strength reduced by reduction of clay content on the addition of an open sand, namely, one with a high permeability. A sand used for an opener should always be chosen by a comparative test, because it has been found that at times a relatively fine sand will open a dense heap sand more readily than a coarser sand.

In Fig. 9 is shown the percentage of boiler casting loss on a certain floor during a period of February and March. The casting loss for the first part of February, where permeability of the heap sand averaged 31, is high and irregular. After the heap was opened up to permeability of 43, the loss dropped consider-

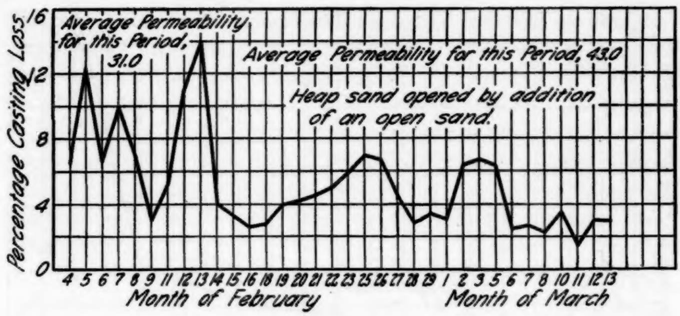


FIG. 9—REDUCTION OF BOILER SECTION LOSS BY INCREASING PERMEABILITY OF HEAP SAND

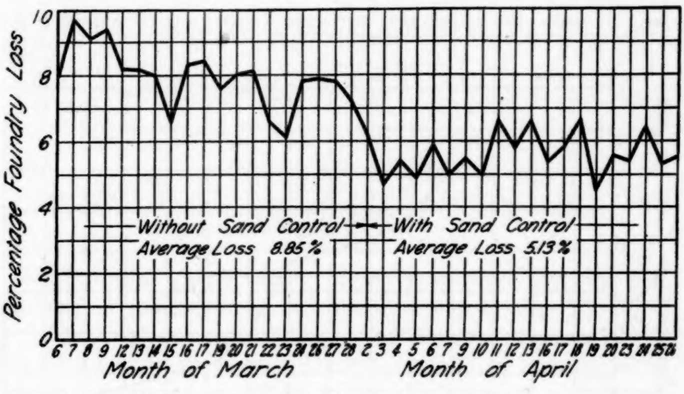


FIG. 10—REDUCTION OF LOSS IN RADIATION SECTION BY APPLICATION OF SAND CONTROL TESTS

able, as shown for the latter part of February and first part of March.

The casting loss was not only reduced but the casting finish improved, less new sand used, definite location of certain loss causes, other than sand, determined, and reduction of excess weight of casting, by possibility of running a thinner metal line, was accomplished.

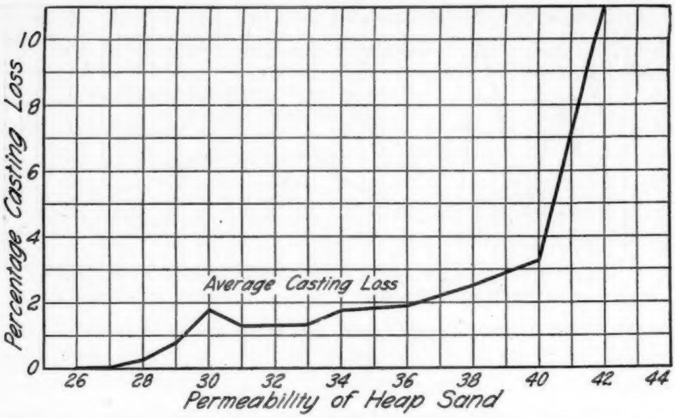


FIG. 11—HIGH PERMEABILITY SHOWING INSUFFICIENT AMOUNT OF SEA-COAL CAUSES LARGE DIRT LOSS

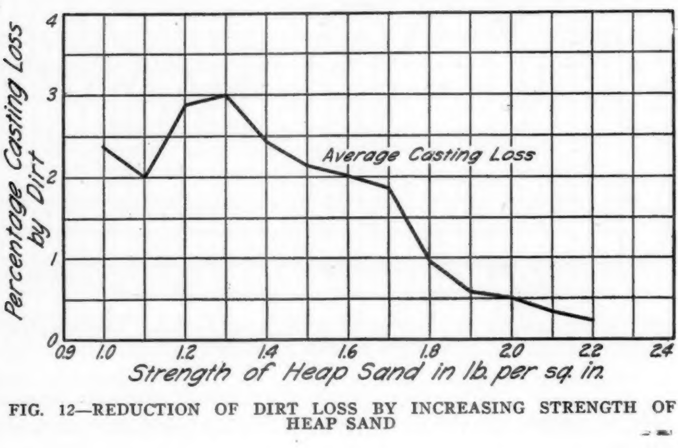


FIG. 12—REDUCTION OF DIRT LOSS BY INCREASING STRENGTH OF HEAP SAND

Sand Test Controls Addition of New Sand

The application of the sand control testing to the radiator molding sand has resulted in a more uniform addition of new sand. New sands are added not just to add new sand but, to produce or maintain certain specific conditions in the heap sand.

Under this control, the heap sand becomes a constant medium for the molders to work with, upon which efficient standardized production methods may be applied.

The effect of this on the foundry loss may be readily seen in Fig. 10. In this figure the loss is shown before and after the application of sand control. The loss during the sand control period is much more constant, due to the elimination of one of the greatest variable conditions of the foundry, namely, sand conditions.

The discovery of certain unfavorable sand conditions which produce losses, may be made by the use of graphs, or other means of comparison and representation. In Fig. 11 is shown a curve

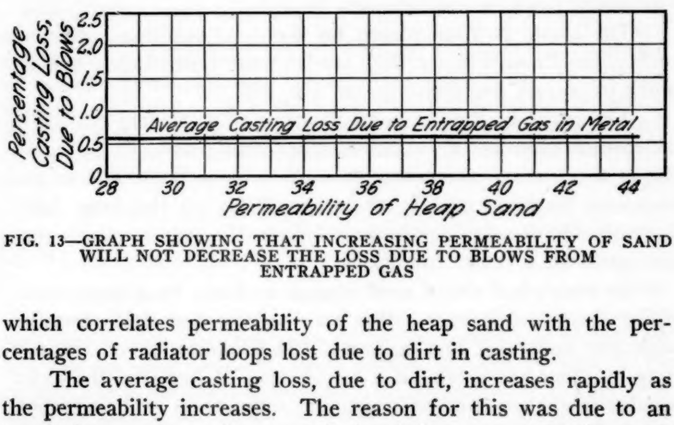


FIG. 13—GRAPH SHOWING THAT INCREASING PERMEABILITY OF SAND WILL NOT DECREASE THE LOSS DUE TO BLOWS FROM ENTRAPPED GAS

which correlates permeability of the heap sand with the percentages of radiator loops lost due to dirt in casting.

The average casting loss, due to dirt, increases rapidly as the permeability increases. The reason for this was due to an insufficient amount of seacoal facing being present in the sand. If sufficient amount of seacoal was in the sand, then the permeability of the sand would drop to a low thirty or a high twenty for this particular sand.

Among the several itemized losses correlated with test data was the strength of the heap sand versus average percentages of radiator loops lost due to dirt. This relation is shown in Fig. 12. The average loss curve shows that chances for dirt loss were greatly decreased by increasing the strength of the heap sand. It also shows that the strength of the heap sand should be above 2.2 pounds to insure a low percentage casting loss due to dirt.

Losses Due to a Number of Conditions

In determining conditions which produce losses, it is well to remember that losses are due to combinations of conditions. For example; certain molders will produce low losses with say fairly weak or heavy sand, while the majority of the other molders will run a high loss. Therefore, it can be expected in the comparison of sand test data and detailed losses that certain weak or heavy floors will not always agree. Very probably several of the poor sand heaps will run low losses. An average of the comparisons is needed to show definitely the change certain conditions produce.

It is the elimination of the chance or probability of a high loss which produces uniform low losses.

The blame is often placed on the sand condition when, in reality, the cause is other than sand. Sand control data will do much to correct this phase of the loss alibi.

The curve in Fig. 13 is an illustration of placing the cause of casting blow on a condition other than sand. This curve shows the average percentage loss of radiator loops due to gas blows, to be unaffected by the permeability of the heap sand. Immediately the sand is eliminated from the search, which pins the cause on a fewer conditions.

At each plant where sand control methods have been established, the foundry organization have become thoroughly familiar with test apparatus and methods. The application of the test data by them has produced a satisfaction of knowing the exact condition of their sand and, also, has aided them in their respective reduction of losses.

Discussion—Commercial Application of Molding Sand Tests

G. Olson: I would like to know if tests were made for life?

H. W. Dietert: Yes, we test the life of molding sand as soon as the sample gets in. On one-half of a gallon sample we run the A. F. A. method tests; you can then determine its maximum permeability. Our next step is to take another sample of this sand, about a double handful, which is approximately a thousand grams; put it in a little pan, and place it in a gas furnace or electric furnace, and heat that sand at 600 degrees Fahr. for two hours. That is a fair degree of heat, and certainly will take out a lot of the strength of the sand, providing it is a weak sand. After it cooled, we ran the strength test and a permeability test on it again, and you will find that all the weak sands have lost a certain portion of their original strength. Suppose the sand ran 200 grams cohesiveness test on the first sample from the pit, and when you get it out of the oven, it only runs 100; it has lost a hundred grams; that is, 50 per cent durability. That is the heat test, or durability test; in other words, it is as close as we can approach to practical conditions, as I see it.

Dr. H. Ries: I would like to ask Mr. Dietert how much reduction in strength he considers permissible in that life test after heating the sand 600 degrees Fahr?

H. D. Dietert: That is a question I am unable to definitely answer at this time. Here is what we are doing: we are allowing for our low bonded sands, our fine sands in certain localities a 20 per cent loss, but not over. For our plants situated in other portions of the country where the molding sand does not have the life of these first sands we have a new range of acceptance, and that is up to 40 per cent loss. Thus, you see we have different limits, depending on what sand we are testing at the time. In several plants, our northern plants, we allow a loss of strength of 20 per cent, and at our southern located plans, a 40 per cent loss of strength. The loss of permeability ranges about 4 per cent.

M. A. Blakey: I would like to ask Mr. Dietert, if it is permissible, what size of organization he uses to make these tests, and I would like to know something about the size of the foundry in which the tests are made. My reason for asking this question is to decide whether it will pay. We must first know how much it costs.

H. W. Dietert: I will give you the detailed cost of our laboratories and the size of the room. For our laboratories and the appa-

ratus in the sand control laboratories, that is, the foundrymen's and superintendent's laboratories, the cost is approximately $225 to $250 for the apparatus complete for sand control. The room required has been 8 feet by 12 feet. We have one 8 x 8, and it is always an annex to the superintendent's office. It is next door, where you have to go through his office to get there. It is his laboratory. The size of the organization or size of the plant where these laboratories are located—they employ approximately, at this time, 300 men, and they melt on an average—our average tonnage would be about 100 tons. The sand floors tested run about 60 floors; 3 samples of the sand are obtained from each floor. One man does all the testing; he also tests every car of sand that comes in and also tests some cores with the same machine. This one man that we choose for sand control work is a practical man, to a large extent; he does not have a laborer's mind, but he is an ambitious man and a fellow that has known molding sand and can mold, and who can talk shop language to the men; who has diplomacy to sway the tempering gang and to do what the superintendent tells him to do without any comeback.

CHAIRMAN BULL: Then you have one man who does nothing else?

H. W. DIETERT: Yes. He is a married man; we choose a man about 40 years old; the young fellows won't work at night.

A Study of the Effect of Heat on the Clay Content of Molding Sands as Shown by the Dye Adsorption Test

By R. F. Harrington, W. L. MacComb and M. A. Hosmer,
Boston, Mass.

Several years of practical foundry experience with similar molding sands as represented by the Millville, New Jersey, so-called gravels obtained from producers operating in neighboring districts has demonstrated conclusively that the clay content of the different gravels varies appreciably. This is frequently true even where mechanical analyses and dye adsorption values on the raw material disclose no wide variation.

Object of Investigation

Recent tests on the fusibility of these clays lead us to believe that their final fusion points are all within the same range.

Believing that the utility of a molding sand depends not only upon the development of the colloidal content in the green clay present, but to the extent to which this property is destroyed under various conditions of heat, the three different clays were subjected to temperatures varying from 212 to 1900 degrees Fahr.

Material Used

Samples of three different gravels obtained from as many producers, all of which gravels were of the same geological formation, and mined from the same district.

Preparation of Clays

The gravels bearing the clays to be tested were so coarse in structure that it was feared that errors due to sampling might be incurred if the dye adsorption tests were made on the gravel itself. By utilizing the principle of washing the clay from the

grains as applied in the mechanical analysis test a sufficient quantity of clay was obtained. For those who are not familiar with the method for making mechanical analyses of molding sands, as adopted by the A. F. A. committee on molding sand research, a few words describing the procedure may be given.

In the presence of a 10 per cent caustic solution the clay was defloculated from the grain and after allowing sufficient time for settling the solution carrying the clay in suspension was decanted into large settling tanks. Here it was neutralized with a weak acid solution causing the precipitation of the clay. The bulk of the moisture was then decanted, the remainder being driven off over the hot plate. The clay was ground to pass through a 200 mesh sieve by means of a disc grinder.

Method of Procedure

Samples of each of the clays were placed in an electric furnace and subjected first to a temperature of 212 degrees Fahr., for one hour. The temperature was at all times under pyrometric control and the variations did not exceed 10 degrees. After cooling, two dye adsorption value tests were made on each sample, and the average result calculated.

The procedure for making the dye adsorption test is as follows:

Twenty-five grams of molding sand dried at 105 degrees Cent., for one hour are weighed into a 500 cubic centimeter wide-mouth bottle fitted with a glass stopper and 300 cubic centimeters of distilled water, plus 5 cubic centimeters of 10 per cent ammonium hydrate, are added. The bottle is then stoppered, sealed with paraffin wax and placed in a suitable rotating machine for one-half hour (any machine making approximately 60 revolutions per minute and upending the bottle with each revolution is satisfactory). At the end of this period 90 cubic centimeters of distilled water are added, plus 5 cubic centimeters of 10 per cent acetic acid. Crystal violet dye is then added in sufficient weight to allow for the adsorption by the colloidal matter and leave a slight excess. For molding sands of weak bond .125 grams of dye is a good amount to start with; the stronger sands require addition of .150 to .300 grams or more of dye. After adding the crystal violet dye the bottle is sealed again

and rotated for another half-hour period. If all the dye is taken up by the colloidal matter an additional weight of dye should be added, as it is necessary that an excess of dye be present over that required to satisfy the adsorption capacity of the colloids.

In order to determine the amount of dye adsorbed by the sand it becomes necessary to find the quantity unadsorbed or held in solution. If the test is allowed to stand over night, suspended material settles out, leaving a clear solution of the dye stuff, and the dye unadsorbed can be determined by color comparison. The standard color solution is made up by dissolving .500 grams of crystal violet dye in 500 cubic centimeters of distilled water, 25 cubic centimeters of the clear dye solution is taken from the test by a pipette and run into one of a pair of "carbon" comparison tubes, such as used in steel analysis, diluted to 50 cubic centimeters volume and thoroughly mixed. Forty cubic centimeters or more of distilled water are added to the second comparison tube and the standard dye solution added from a burette until the color matches that of the test in question, taking care that the final volume is the same in both tubes. If it required 2.5 cubic centimeters (.0025 grams) in the standard tube to match the color in the test, then we have .0025 grams of dye unadsorbed in 25 cubic centimeters or .040 grams in 400 cubic centimeters. This figure is subtracted from the amount of dye added to the test, multiplied by four and the result expressed as milligrams of dye adsorbed per 100 grams of sand.

Study of Result

A. Gravel X (Refer to curve of Fig. 1).

A gradual and uniform decrease in the colloid content is obtained as the temperature was increased from 212 degrees Fahr. to 1,000 degrees Fahr. At 420 degrees Fahr. the decrease in the colloidal content was 9.2 per cent while at 1,000 degrees it was 51.8 per cent.

Between the temperatures of 1,000 degrees and 1,400 degrees the decrease in dye adsorption value is less rapid.

From 1,700 degrees to 1,900 degrees the destruction of the colloids must be extremely rapid. With the latter temperature

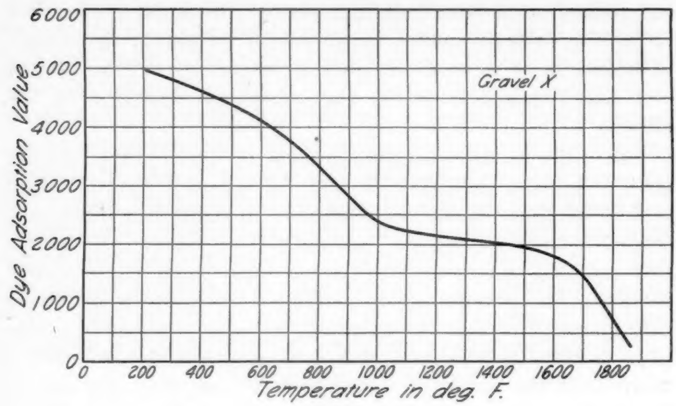


FIG. 1

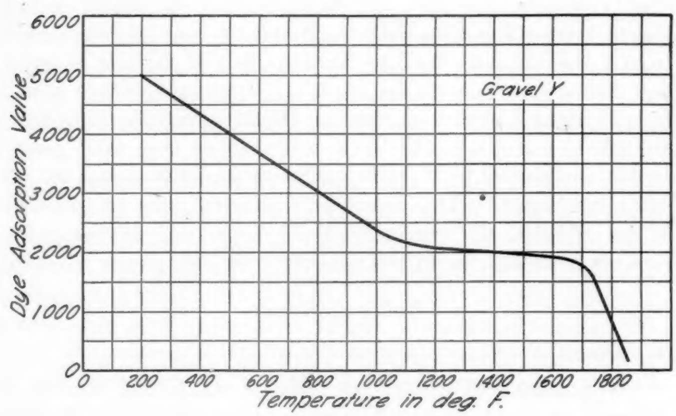


FIG. 2

a dye adsorption of 260 as compared with the value of 4,980 on the original clay is obtained.

B. Gravel Y (Refer to curve of Fig. 2).

Beginning with the dye adsorption value of 5020 when heated to 212 degrees we find the value decreases slowly and

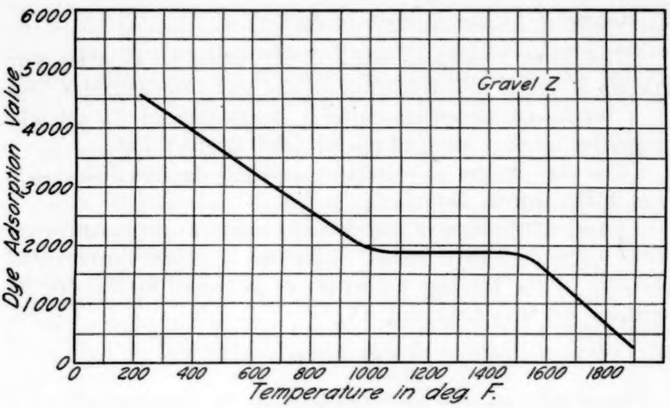


FIG. 3

uniformly until a temperature of 1,000 degrees is reached. The value of 2,360 or a 53.0 per cent drop is noted at this temperature.

Comparable with the clay from gravel X the decrease in colloid content between the temperature range of 1,000 degrees and 1,300 degrees is very slow. At 1,000 degrees it dropped 53.0 per cent while at 1,300 degrees a drop of 59.4 per cent is noted.

A very rapid decrease in dye adsorption value after the temperature exceeds 1,700 degrees takes place. At 1,900 degrees 97.6 per cent of the colloidal property is destroyed.

Table 1

Tabulation of Results

Temperature Degrees Fahr.	Dye Adsorption Clay X	Per cent Drop	Dye Adsorption Clay Y	Per cent Drop	Dye Adsorption Clay Z	Per cent Drop
212	4980	....	5020	....	4480	....
420	4520	9.2	4320	13.9	3940	12.0
500	4360	12.4	4160	17.1	3640	18.7
600	3760	24.5	3500	30.3	3040	32.1
700	3760	24.5	3260	35.1	3040	32.1
800	3240	34.9	3080	38.6	2760	38.4
900	2800	43.8	2720	45.8	2240	50.0
1000	2440	51.8	2360	53.0	1840	58.9
1100	2250	54.8	2180	56.6	1880	58.0
1200	2170	56.4	2080	58.6	1880	58.0
1300	2120	57.4	2040	59.4	1910	57.4
1400	2280	54.2	....	....	1920	57.1
1700	1480	70.3	1820	63.7	1160	74.5
1800	480	90.4	400	92.0	410	90.9
1900	260	94.8	120	97.6	280	93.7

C. Gravel Z (Refer to curve of Fig. 3).

The same conditions which were found to be true with gravels X and Y also hold true for the clay from gravel Z, that is, a rapid and somewhat uniform destruction of its colloidal properties up to a temperature of 1,000 degrees Fahr.

The clay is just as refractory at 1,400 degrees Fahr. as it is at 1,000 degrees Fahr.

Rapid destruction of the colloid content as temperature exceeds 1,700 degrees is noted. Likewise, at 1,900 degrees 93.7 per cent of the bonding properties as measured by the dye adsorption test was destroyed.

Conclusions

The results of the test substantiate the information of a condition, which, based upon foundry practice, was held to be true, namely, that the clay from gravel X has a longer life than either of the other two. At 700 degrees Fahr., only 24.5 per cent of the bonding property of X is destroyed, compared with 35.1 per cent and 32.1 per cent, respectively, of Y and Z.

When using any of the three gravels under consideration, the clay portion which comes within immediate contact with the molten iron must be fused to such an extent as to destroy completely its bonding property.

Two clays may have equal dye adsorption values and also have the same ultimate fusion point, yet one may be much better adapted for molding purposes than the other.

Discussion—A Study of the Effect of Heat on Clay Content of Molding Sand

CHAIRMAN R. A. BULL: I would like to ask Mr. Harrington, in starting a discussion on this interesting paper, if any effort was made to make cohesiveness tests, after the treatment by these different temperatures, and to check the results of those tests against the dye adsorption test?

R. F. HARRINGTON: On our previous work, it had been impossible to obtain from the cohesiveness test the apparent true working conditions in the foundry, as far as the life of the clay was concerned. That is why we turned to the dye adsorption test, to see if that would

not throw some light on it and provide gravel in actual practice capable of running the shop with a 24 per cent addition, instead of 35 per cent. This paper was based on only a few notes we had obtained; unfortunately, due to the fire we had in one of the laboratories and the illness of the man who was doing the actual work, the paper was not anywhere nearly as complete and clear as we wished it to be.

H. FRECHETTE: I would like to know something about the type of furnace in which the heating experiments were conducted.

R. F. HARRINGTON: It was a muffled type of electric furnace. Those fusing point tests were determined in a so-called high temperature furnace manufactured by one of the copper manufacturers, and some samples were sent to one of the steel corporations and checked at that point, and the tests were made in a similar electric furnace.

H. W. DIETERT: Do you feel that the cohesiveness strength is the total of of the dye adsorption and physical bonding strength of the sand?

R. F. HARRINGTON: I had anticipated that question being asked, and I do not feel that I am at all prepared to say. We have not called the dye adsorption test supplementary; we feel as though, particularly in its relation to new sand and new sand testing, it should hardly be relegated to what we might call a supplementary test of cohesiveness. We have had several years of work in using dye adsorption tests before the cohesiveness was developed as a means of determining the life of our sand and keeping up the quality of the heap. That is, we purchase sand with a minimum amount of clay content, with the greatest amount of value as indicated by the dye adsorption test. We feel when we purchase sand that we want the sand that has the best quality of clay, as indicated by the dye adsorption test, and that means that the heap is clogged up to a less extent by a large quantity of clay. Then we are able, by using the sand that has a high dye adsorption value, to use a lesser amount of that sand to maintain the strength of the heap than by using sand that has a low adsorption value.

CHAIRMAN R. A. BULL: Mr. Dietert, you might tell us whether you have made use of the dye adsorption test, and compared it to get results by which you can more intelligently purchase sand?

H. W. DIETERT: I have not, because I do not feel that the dye adsorption test gives the physical strength of a molding sand. I believe it gives the chemical strength of the clay content, but does not take into account the strength that the sand obtains from the size of the sand grains and the shape of the sand grains and other physical properties that are inherent to that particular sand; so I do not believe that the dye adsorption test gives or conveys a definite means of expressing strength to the foundryman.

R. F. HARRINGTON: May I reply to that and point out that the quality of the heap sands to which this new sand is added is not meas-

ured by the dye adsorption test, but is measured by the cohesiveness test, but the new material entering that heap, its quality and ultimate effect on the strength of the heap, is measured by the dye adsorption test and has proved over a period of years to be a very fair indicator of what that sand will do in the heap. We control the heap by the cohesiveness test, but we believe that the amount of work done by that new sand will be based to a considerable extent on the condition of the collodial content, and that this condition is indicated by the dye adsorption test. It has proven out practically in actual foundry practice.

H. W. Dietert: A different point of view has been conveyed to me by Mr. Harrington in regard to the dye adsorption test. Do you feel that it is better suited for research of sand than it is for control work and that it shows a property that is not shown distinctly by the cohesiveness test? In other words, that it furnishes you with a little more data but not absolutely essential to the foundryman? In other words, in our foundry sand work, we have tried to eliminate every possible complication that may enter into sand testing, and in that manner I tried to keep dye adsorption out of these laboratories. I realize that it can and does furnish a very valuable study in research on molding sands, but I do not think it is essential.

Chairman Bull: Your point is that it is a valuable factor in guiding the purchasing and selection of the new material?

R. F. Harrington: Yes, sir; this whole paper was prepared on some notes taken when we were endeavoring to obtain the relative merits of three Millville gravels from New Jersey, and we checked up the results in a theoretical way from three or four weeks' run in the foundry, and found that they checked identically and that is the result of a considerable period of time. I do not approve of the dye adsorption test as a measure of the condition of a heap under any condition, because the sand heap is contaminated by seacoal and other material, but in purchasing raw material we have found it a very valuable guide. That is based on the practical experience of 5 or 6 pears.

H. W. Dietert: Would the cohesiveness test give you the details of the properties of molding sand? Could you eliminate the dye adsorption as we have eliminated various permeability apparatus for simplification?

R. F. Harrington: I am really not prepared to answer that. It is barely possible that the cohesiveness test might prove to be a test that we could use to do away with the dye adsorption test, but I cannot see it as yet.

H. M. Lane: Is it not true that these two gentlemen are working with such radically different sands that the dye adsorption test fits the coarse sand, the clay in it, while the relatively fine sand used in the radiator trade might not need any such treatment?

H. W. Dietert: We do use a coarse sand for the boilers, and I believe it is almost as coarse as some that Mr. Harrington used. I

believe the issue is whether the cohesiveness test displaces the dye adsorption test.

R. F. HARRINGTON: I think that absolutely is the point of issue. I expected it to be raised.

CHAIRMAN BULL: Well, it is an interesting point to be raised if discussion and further consideration will only lead to more progress.

A. A. GRUBB: Just one consideration there; it seems to me that the dye adsorption test cannot be laid aside, as yet, at least, for this reason: our present method of investigating sands stops at separating the clay, if we drop the dye adsorption test. The dye adsorption test goes further, it is measuring that clay, and I believe that if the investigation of the nature of the clay is going to answer a great many problems that we now have, the answer to which is not clear, that the clay should be subjected to a fineness test that is as complete as our present sieve test is on the raw sand, because the forces which come into play in causing bond are tremendously stronger with the finer particles. We cannot sift that clay by a sieve, but we can measure its surface, not necessarily the outside surface of the grain, but every bit of surface, even the pores of each grain, by the dye adsorption test. We have made investigations at the Ohio Brass Company in measuring bond with that dye adsorption test and we find that some sands which are very fine, so far as the sieve test is concerned, have a certain amount of bond, but are almost negligible in the dye adsorption test, for these sands are lacking in clay material. Therefore, I will just leave this for you. We certainly want to retain that dye adsorption test because it is the only method we have at present to investigate that field which is of the utmost imporance in bond.

R. F. HARRINGTON: It seems to me that by making the cohesiveness test on the bar and neglecting the dye adsorption test, we are almost assuming that because that sand is capable of producing a given cohesiveness test on the new material, it is equally capable of producing the same result when it goes into the heap. I question as to whether it is capable of doing that; in other words, compared to a furnace proposition. We measure the tensile strength of the iron and assume that when it goes through, it is going to have the same effect on the metal it goes into. Now, is it fair to assume that because a raw sand has a cohesiveness value very high, that it will contribute equally high cohesiveness value in the heap, while all the other conditions of the heap, maybe 80 per cent of them, differ as to grain size, amount of fine material present, etc.?

CHAIRMAN BULL: Mr. Saunders, you have had a good deal of experience in dye adsorption test, we would like to have your ideas on that point.

W. M SAUNDERS: The dye adsorption test probably originated in our laboratory 15 years ago, and I have tested many hundreds of sands

since, both new and in the heap condition. As a test for the heap, I do not believe it can be depended upon. For Albany sands, I think it can be: in fact, we ran one foundry for about a year just keeping track of the heap by the dye adsorption test alone. For some of the other sands, it is doubtful whether the heap sand can be controlled by the dye adsorption test, but new sands can be judged almost perfectly by applying the dye adsorption test. Now, there is one point I think that has been overlooked in this discussion, and that is the condition of the clay substance around the grains of sand. The dye adsorption gives you the total bonding clay substance, while the cohesiveness test only shows you the strength of the sand due to certain conditions of the bonding clay around the grains. That is, the clay substance may not be evenly distributed around the grains and you get a low bonding or cohesiveness test, whereas the dye adsorption would be a high test. Manipulating sand or mixing it with other sands, changes the condition of the bonding material and you get a higher bonding test, but you do not change the dye adsorption.

R. F. Harrington: Are we not assuming, then, in using the cohesiveness test as an actual measure of what that sand will do in the heap, that that collodial property will wrap itself around the 80 per cent of the old sand and do what it did in the new sand? We found in actual experience that we could separate the clay from a Millville gravel and then bring the clay and the grain back together again and make a perfect sand, so far as field use goes, but when we attempted to put another clay back on those grains, we could not do it at all. Now, the cohesiveness test, as applied to raw sand, would seem to indicate that we believe it is possible for the colloids in the new sand to wrap themselves around the old grain in exactly the same manner that they do in new sand, when new is added to old sand. Have we got any proof that they do wrap themselves around the old grains in the same per cent as they do in the new grains, which gives them a high cohesiveness? I have yet to see the proof that they do that. That is why I am not prepared to drop out the dye adsorption test.

H. Ries: I haven't any special contribution to make to this discussion. I simply want to stir up more trouble. In making the dye adsorption test, I believe it has been customary to use crystal violet dye. Now, that is regarded as an acid dye which will react with basic colloids. I would like to see somebody try some other dyes. I believe Sanford is a basic dye; I would like to see someone try that dye on these basic sands and see what result they would get. There is more work for you, Mr. Harrington.

Chairman Bull: That is a constructive suggestion.

R. F. Harrington: I think your point is well taken. I am talking from a more or less practical standpoint, and am going on the basis of work for over five or six years and the fact that this has proven practical for that time.

The Physical Properties of Foundry Sands

By C. A. Hansen, Schenectady, N. Y.

This paper is primarily a record of the results obtained in an endeavor to correlate the various measurable properties of a few simple sands and to find simple relationships between them.

Very little systematic information appears to be available in the technical literature regarding the properties of dry molding sands, and an effort has therefore been made to extend laboratory investigations into this field.

From these results, and from similar results obtained in less detail with several other sands, the writer has formed certain tentative opinions which it would be premature to classify as conclusions, but these opinions are expressed in the hope that they may be considered suggestive.

Sands Tested

Two sands were selected which were approximately alike in average grain size and fairly similar in shape of grain, one a naturally bonded coarse Albany sand, the other a sharp Jersey silica sand to which 5 and 10 per cent clay was added.

The sharp silica sand, Cedarville No. 2, is a fairly close approach to Ottawa silica sand in its grain character. This sand was set up as an arbitrary laboratory standard for the testing of binders. It was bonded by addition of Kraus No. 401 clay, a clay which had likewise been set up as an arbitrary standard in testing clays and for bonding sharp silica sands for testing purposes. It so happens, then, that a considerable amount of laboratory data has been collected with respect to these two materials and some of these data have been used to weight the deductions drawn from the particular investigation here discussed.

The naturally bonded Albany sand was selected as being the most nearly uniform in grain size of some 15 coarse Albany sands collected during a recent inspection trip. It was loaded from a large bank just north of Mechanicsville, N. Y. It may be classified as a No. 3½, 4 or 5 to suit the numerical idiosyncracies of the individual purchaser.

The screen analyses of the two sands are given in Table 1. The sands were washed in dilute alkali in the usual manner to remove clay and screened through a nest of standard Tyler screens on a Rotap machine.

Table 1

Screen Analyses of Cedarville No. 2 Sharp Silica Sand and Washed No. 3 1/2 Albany Sand

Screen Meshes per Linear Inch.	Linear Mesh Opening, Mils	Albany Sand Cumulative Per Cent	Albany Sand Fraction Per Cent	Cedarville Sand Cumulative Per Cent	Cedarville Sand Fraction Per Cent
6	131	0.45	....	....	.....
8	93	0.55	0.10	....	.....
10	65	0.80	0.25	....	.....
14	46	1.20	0.40	....	.....
20	32.8	2.70	1.50	....	.....
28	23.2	6.30	2.60	0.00	.....
35	16.4	16.5	10.2	0.40	0.40
48	11.6	49.0	32.5	16.5	16.1
65	8.2	72.7	23.7	64.0	47.5
100	5.8	80.5	7.8	90.0	36.0
150	4.1	84.0	3.5	97.5	7.5
200	2.9	86.5	2.5	99.6	2.1
270	2.1	88.5	2.0	99.94	0.34
—270	1.0	100.0	11.5	100.0	0.06

Per cent clay: Washed sand the 100 per cent basis.......... 13.0 0.0
Predominant (weight) grain size, mils........................ 12.5 10.0

The Cedarville sand is an essentially uniform sand. The washed Albany sand contains some 16 per cent of its total weight that is coarser than the coarsest Cedarville grain and some 11 per cent that is finer than the finest Cedarville grain.

Preparation of Sands for Test

Sufficient sand for an entire group of tests was set aside until air dried at room temperature. The dried sand was mixed and drawn upon as needed.

Four kilogram portions of sand were milled and tempered in a small chocolate mill shown in Fig. 1. Nothing but water was added to the Albany sand. Finely powdered Kraus No. 401 clay was added in the proportions 5 and 10 per cent to the dry Cedarville sand; the mixture was milled one minute, then tem-

pered, and milled an additional five minutes. Further milling is known to serve no purpose.

The tempered sands were set aside in sealed one gallon tins to age for 24 hours or more, screened through a 4 mesh sieve to remove oversize and to insure uniform moisture distribution, and then tested.

Testing Methods Used

Density: The actual densities of the dry sands were determined by boiling the sand in benzol to displace air and then

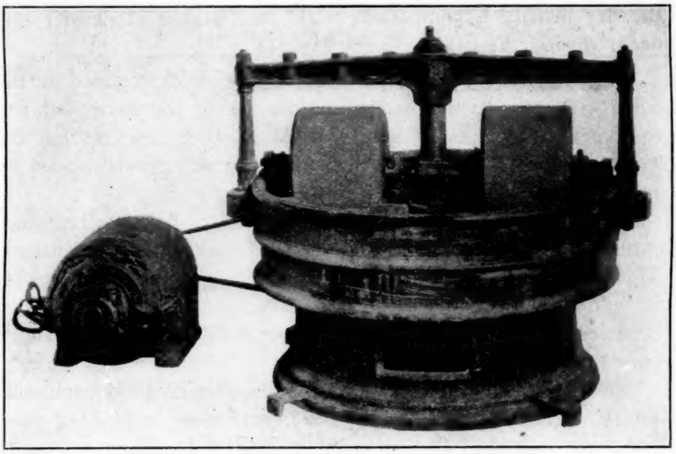


FIG. 1—PHOTOGRAPH. SAND-MIXING MILL

weighing in benzol. The density of the Cedarville sand is 2.65, that of the Albany sand 2.67.

Hereinafter, the term density refers to the ratio of weight to overall volume—i. e. apparent density—unless otherwise specifically stated.

Sand was weighed into brass tubes 2.000 inches inside diameter by 6.125 inches length. Cores approximately 2 inches high were formed under a falling weight type of ramming device and the height of the core was measured without removing it from the tube in which it was formed. A brass disc 0.125 inches thick by 0.75 inches diameter was let down upon the core surface and

the distance between the disc surface and the upper edge of the brass tube was determined by means of a 6 inch depth gauge calibrated to 0.01 inches. The green density was calculated from the determined weight and volume; the percentage of voids was calculated from the known green density, the actual density, and the known moisture content.

Dry densities (baked cores), were determined by measuring and weighing strength test cores. The accuracy of these determinations is low compared with the accuracy of the method above outlined, so low that the mean error of determination of the dry density is comparable with the changes in density that occur during the baking operations.

Permeability: Green permeabilities were determined on the cores used for density determinations, using the unrevised test equipment (A. F. A. Trans. Vol. 31, p. 698), except that the wooden base of the standard ramming device was replaced by a heavy steel base.

Dry permeabilities were determined by baking the green cores in the tubes in which they were formed and retesting them. This method is objectionable when the core changes appreciably in volume during the baking operation, in that the core either becomes loose in the tube or is in part crushed by its own tendency to expand.

Green Bond or Cohesiveness: The standardized equipment (A. F. A. Trans. Vol. 31, p. 687), was used in making these tests, the ramming device being a 4 inch diameter steel tube through which a 20 pound weight was permitted to fall. The guide tube was supported rigidly from a heavy steel base which, in turn, was rigidly fastened to the top of a heavy work bench.

The results of these tests are reported in terms of pounds per square inch maximum fiber stress instead of in the usual units; first because the usual unit is not a rational one, and second, because it was deemed preferable to report all strength results in common terms.

The strength unit here used was determined according to the following equation:

$$S = \frac{0.00557}{W} \times \left(\frac{w}{d}\right)^2$$

where S is the strength in pounds per square inch, W is the weight of the full core in grams, w is the weight of the broken fraction in grams, and d is the thickness of the core in inches. The unit usually reported is equal to w/d as above.

Green Compression Strengths: A method of determining the green compression strength of sand cores was developed in an effort to reconcile the differences between two tests that frequently contradict one another, the cohesiveness test and the familiar hand squeeze bond test of the foundry man. This contradiction will be referred to again later. The method developed

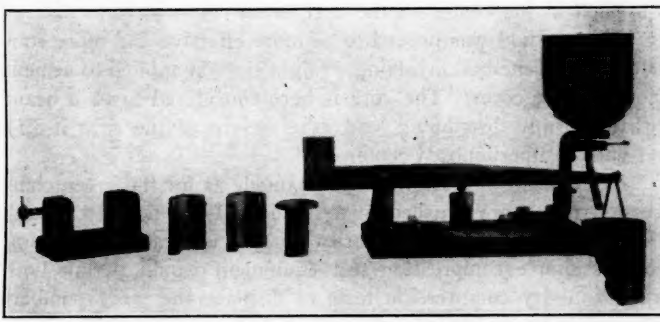


FIG. 2—PHOTOGRAPH. GREEN COMPRESSION TEST EQUIPMENT

failed to serve the purpose intended; in general its results agree with those of the cohesiveness test. The method itself, however, appears to have the merit of being simpler than the cohesiveness test and to possess a materially higher inherent accuracy.

The equipment required is pictured in Fig. 2. Sand sufficient to make a core 1.50 inches diameter by 1.50 inches in height (usually 70 to 80 grams) is weighed into a split core box which is held together in a screw clamp base. The sand is compacted in the usual permeability test ramming device and the resulting core is broken in compression under a 3 to 1 lever beam by applying a lead shot load.

It is definitely known that when various samples of the same sand mixture are equally rammed (foot pounds/unit volume) the compression strength is inversely proportional to the height

of the core (limits tested 1 to 2 inches). With equally high cores, the strength increases more rapidly with increase in density than does the cohesive strength. The observed strength is about as insensitive to the rate of loading as in the cohesiveness test, and both tests are susceptible to standardization of the rate of loading.

Dry Crossbending Strengths: Cores, made as for the cohesiveness test, were cut into two equal lengths, baked over night in an electrically heated oven—at 110 to 120 degrees Cent. unless otherwise stated, and broken in the beam machine shown in Fig. 2. The core supports are 6 inches apart and the load is applied at the center of the core beam.

This method was proved to be more effective and more consistent than a method involving straight tension applied to cement briquette type cores. The core is here considered to be a beam with uniformly distributed load (the weight of the core itself) and with a superimposed center load.

Dry Crushing Strengths: Cores, made as for the green compression test, were crushed in a standard 1,000 pound capacity Riehle testing machine, primarily with a view to ascertaining whether simple compression test equipment would permit both green and dry compression tests to displace the more cumbersome cross bending tests for general routine work. These tests were only very recently undertaken and insufficient work along this line has as yet been done to warrant definite recommendations.

The Reduction of Test Data

All sands were tempered over the entire range of moisture —quite too dry for practical use, too excessively wet for practical use. Each sand mixture was tested for density, permeability, and strength with ramming as a variable, ramming being expressed in terms of foot pounds applied per cubic inch of final core volume. Each series of such test results was plotted and data corresponding to predetermined degrees of ramming were interpolated.

The interpolated data were again plotted with moisture content as a variable, and a second series of data corresponding to predetermined moisture contents were interpolated.

Table 2

Tests of Three Sands

Cedarville Sand Plus 5 Per Cent Clay

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
Green density—					
2	1.474	....	....	1.634	0.160
4	1.514	....	....	1.668	0.154
6	1.561	....	....	1.706	0.145
8	1.608	....	....	1.744	0.136
10	1.654	....	....	1.783	0.129
Calculated dry density—					
2	1.445	....	....	1.601	.....
4	1.453	....	....	1.601	.....
6	1.483	....	....	1.604	.....
8	1.479	....	....	1.604	.....
10	1.489	....	....	1.605	.....
Green voids, volume per cent—					
2	42.6	....	....	36.2	.....
4	39.1	....	....	32.8	.....
6	36.3	....	....	29.2	.....
8	31.3	....	....	25.4	.....
10	27.3	....	....	21.6	.....
Green permeability, A. F. A. unit/250—					
2	0.72	0.58	0.46	0.34	.....
4	0.64	0.50	0.38	0.28	.....
6	0.54	0.41	0.30	0.21	.....
8	0.45	0.32	0.22	0.15	.....
10	0.36	0.24	0.15	0.07	.....

Cedarville Sand Plus 10 Per Cent Clay

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
Green density—					
2	1.510	....	....	1.778	0.268
4	1.551	....	....	1.755	0.204
6	1.608	....	....	1.769	0.161
8	1.661	....	....	1.806	0.145
10	1.714	....	....	1.851	0.137
11	1.741	....	....	1.876	0.135
Calculated dry density—					
2	1.478	....	....	1.742	.....
4	1.489	....	....	1.682	.....
6	1.502	....	....	1.663	.....
8	1.528	....	....	1.662	.....
10	1.543	....	....	1.666	.....
11	1.550	....	....	1.669	.....
Green voids, volume per cent—					
2	41.1	....	....	30.6	.....
4	37.6	....	....	29.2	.....
6	33.7	....	....	26.6	.....
8	29.1	....	....	22.8	.....
10	24.7	....	....	18.6	.....
11	22.4	....	....	16.3	.....
Green permeability, A. F. A. unit/250—					
3	0.53	0.38	0.27	0.17	.....
4	0.49	0.34	0.24	0.15	.....
6	0.39	0.28	0.20	0.13	.....
8	0.28	0.20	0.13	0.066	.....
10	0.19	0.13	0.074	0.029	.....

No. 3½ Albany Sand (13 Per Cent Clay)

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
Green density—					
2	1.754	....	....	1.834	0.080
4	1.677	....	....	1.819	0.142
5	1.660	....	....	1.832	0.172
6	1.670	....	....	1.870	0.200
8	1.776	....	....	1.990	0.223
10	1.890	....	....	2.115	0.225
Calculated dry density—					
2	1.718	....	....	1.797	.....
4	1.610	....	....	1.746	.....
5	1.577	....	....	1.740	.....
6	1.570	....	....	1.762	.....
8	1.634	....	....	1.841	.....
10	1.701	....	....	1.903	.....
Green voids, volume per cent—					
2	32.1	....	....	29.0	.....
4	33.1	....	....	27.3	.....
5	32.6	....	....	25.7	.....
6	31.2	....	....	22.8	.....
8	23.6	....	....	15.2	.....
10	17.5	....	....	7.5	.....
Green permeability, A. F. A. unit/250—					
3	0.042	0.030	0.021	0.013	.....
4	0.088	0.061	0.043	0.026	.....
5	0.195	0.126	0.082	0.047	.....
6	0.330	0.200	0.120	0.063	.....
7	0.320	0.190	0.110	0.055	.....
8	0.250	0.150	0.088	0.044	.....
10	0.170	0.060	0.021	0.006	.....

Table 2—Continued

Tests of Three Sands

Cedarville Sand Plus 5 Per Cent Clay

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
Green bond strength, lbs. per sq. in.—					
3	0.93	1.11	1.35	1.63	.....
4	0.61	0.73	0.86	1.03	.....
6	0.39	0.47	0.55	0.65	.....
8	0.36	0.43	0.50	0.59	.....
10	0.35	0.42	0.49	0.58	.....
Green compression strength, lbs. per sq. in.—					
2	1.80	....	....	4.80	.....
4	1.10	....	....	2.10	.....
6	1.04	1.25	1.52	2.00	.....
8	1.00	....	....	1.90	.....
10	....	....	....	....	.....
Dry crossbending strength, lbs. per sq. in.—					
2	6.8	9.0	11.4	13.8	.....
3	15.6	20.0	25.6	34.5	.....
4	25.4	33.0	40.2	49.0	.....
6	31.8	39.0	46.2	55.5	.....
8	34.8	42.2	48.9	58	.....
10	37.0	45.0	51.6	61	.....

Cedarville Sand Plus 10 Per Cent Clay

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
3	2.00	2.60	3.29	4.05	.....
4	1.36	1.77	2.18	2.72	.....
6	0.78	1.00	1.22	1.52	.....
8	0.58	0.74	0.90	1.12	.....
10	0.52	0.64	0.76	0.94	.....
3	Not determined				
4					
6					
8					
10					
3	..	...	...	...	.....
4	42	47	52	58	.....
6	63	76	88	105	.....
8	81	95	108	126	.....
10	90	104	117	135	.....
11.2	92	106	119	137	.....

No. 3½ Albany Sand (13 Per Cent Clay)

Moisture as Molded Per Cent	Ramming-Ft. Lbs. per Cu. In. 1	2	4	10	Core B
3	0.54	0.78	1.02	1.34	.....
4	0.99	1.34	1.68	2.16	.....
5	1.39	1.84	2.28	2.88	.....
6	1.37	1.77	2.16	2.68	.....
8	0.72	0.96	1.20	1.52	.....
10	0.54	0.70	0.85	1.06	.....
3	3.0	4.5	8.0	13.4	.....
4	3.5	5.8	9.8	17.1	.....
5	3.7	5.6	9.6	17.2	.....
6	3.4	5.1	8.3	14.3	.....
8	3.1	4.3	6.4	10.7	.....
10	2.8	3.6	5.1	8.2	.....
4	0	1.0	2.5	4.5	.....
6	4.5	8.0	11.0	15.5	.....
8	11.0	15.5	20.0	26.0	.....
10	18	24	31	39	.....
Dry compression strength, lbs. per sq. in.—					
3	0	0	1	8	.....
4	0	3.5	8.5	17	.....
5	3	8.5	19	35	.....
6	7	16	31	53	.....
8	23	40	60	95	.....
10	70	82	100	145	.....

The results summarized in Table 2 and plotted in the charts here reproduced are thus doubly interpolated. In general, each determined point is the average of the results of two to six presumably identical tests. The deviation of the determined mean point from the corresponding point on any of the plotted charts is less than the difference between the results which were averaged to obtain the mean result, so that the writer does not believe that the double interpolation is in any way misleading. The results obtained for one particular sand were not permitted to influence the reduction of results for any other sand, so that a final cross reference of sands also seems to be properly possible.

The relations developed herein between ramming and density, ramming and permeability, ramming and strength, and the various relations between density, permeability and strength derived therefrom have been studied in considerable detail for a number of quite widely different sands and it is the writer's belief that these relations are fairly characteristic of sands in general.

No satisfactory method, so far as the writer knows, has been developed which will indicate to what extent, in work units per unit core or mold volume, a given foundry core or mold has been rammed. Some sort of an estimate is possible from observation and calculation. From this sort of reasoning, the writer believes that the probable range of practical foundry ramming lies between 0.5 foot pounds per cubic inch of core for light oil sand cores and some 6 foot pounds per cubic inch, for heavily rammed steel foundry molds. The results here considered cover the range 1 to 10 foot pounds per cubic inch and the results actually determined cover the range 0.3 to 20 foot pounds.

The Density of Compacted Sands

The density of a compacted sand varies linearly with the logarithm of the work done in compacting it. This is clearly indicated in Fig. 3 (ABC).

$$D = A + B \operatorname{Log} W$$

where D is the density, W is the work done upon unit core volume (foot pounds per cubic inch are the units here used), A is

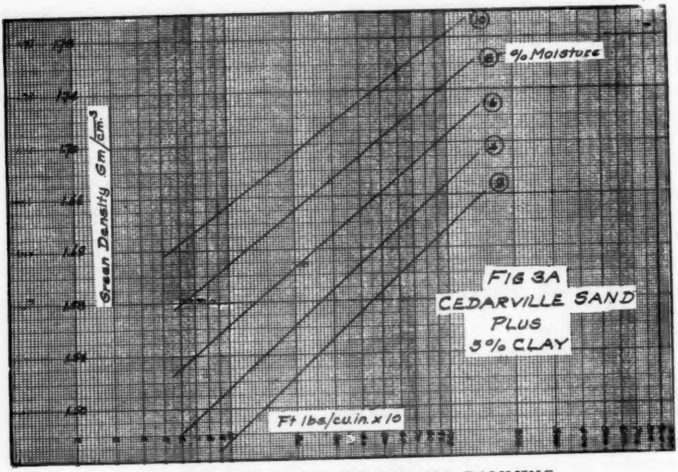


FIG. 3A—GREEN DENSITY VERSUS RAMMING

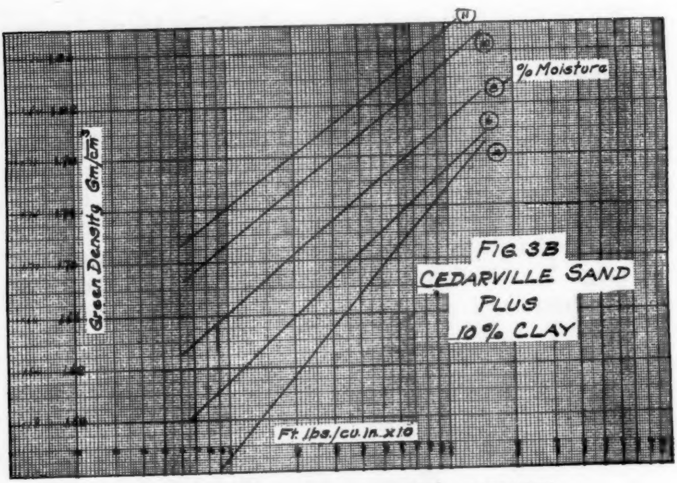


FIG. 3B—GREEN DENSITY VERSUS RAMMING

a constant, numerically equal to the density corresponding to unit work, which determines the vertical elevation of the curves in Fig. 3, and B is a constant which determines the slope of the curves, numerically equal to the difference in densities corresponding to 1 and 10 units work—the 10 base logarithm assumed.

The equation is illogical in that its density limits are zero and infinity—both absurd. It has, however, been tested for some 30 widely different sands at one or more tempers over a range of 0.7 to 15 foot pounds per cubic inch ramming, and for several sands over the range 0.3 to 40 foot pounds, and it appears to agree rigidly within these limits. It does not appear to matter

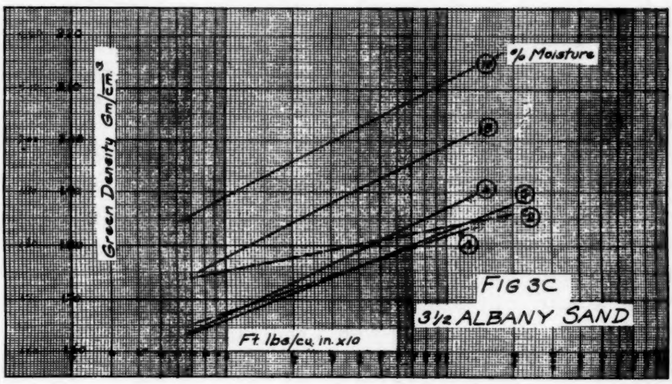


FIG. 3C—GREEN DENSITY VERSUS RAMMING

whether the core be 1 or 3 inches tall, nor does it appear to matter whether the sand is compacted with a series of light blows or with a single equivalent heavy blow.

Initially, density determinations were made with cores compacted with the standard wooden base permeability test rammer firmly attached to the top of an exceptionally heavy work bench. Comparative tests were made with cores compacted with the cohesiveness test rammer—the latter fitted with a heavy steel base similarly fastened to an exceptionally heavy work bench. The comparisons indicated that 32 foot pounds and 10 foot pounds with the respective rammers led to identical densities. By re-

placing the wooden base of the permeability test rammer with a heavy steel base, 4 inches x 8 inches x 16 inches and weighing about 125 pounds, the two rammers were brought into reasonable agreement. A fairly consistent difference still exists, 9.5 and 10 foot pounds for the altered permeability test rammer and cohesiveness test rammer respectively are now equivalent; the relative effectiveness is in the ratio of the logarithms of 9.5 and 10, so slight a difference that it has been ignored. It is evident that work, to be effective, must be absorbed in the sand rather than in elastic hysteresis of the ramming device mounting.

The green density of Cedarville sand plus 5 per cent clay increases steadily with increasing moisture content—there is no inversion point in the moisture-density curve. When the clay content is increased to 10 per cent, the green density increased steadily with the moisture content over the moisture range covered—3 to 12 per cent, but extrapolation indicates the possibility of an inversion point below 3 per cent moisture. There is a very definite inversion point for the Albany sand, a minimum density at about 5 per cent moisture.

The calculated dry densities are of interest in that they indicate that regardless of moisture content Cedarville sand compacts to a virtually specific content of dry sand per unit volume when it is heavily rammed. The difference between the dry densities of Cedarville sand with 5 and with 10 per cent clay indicates that the sand grains are about equally close together in both; the clay has been forced into the interstices between sand grains. The much higher dry density of the Albany sand indicates that the fine silt (—270 mesh grains), as well as the clay, is crowded into the interstices between the predominant grains.

When sands are lightly rammed, it seems that the clay must be rendered plastic before it will crowd freely into the interstices between sand grains. Its plasticity is increased or, if you like, its viscosity is decreased by the addition of moisture. This is reflected in a consistent increase in dry density with increasing moisture content.

When compacted green sand cores were baked, changes in volume occurred, but the changes were so slight that they were difficult to measure with any accuracy. Apparently, Cedarville

sand molded at low moistures changed inappreciably in volume; at high moistures the volume quite definitely decreased, by perhaps as much as 2 per cent for the 10 per cent clay mixtures, and rather less for the 5 per cent mixtures. The Albany sand cores quite definitely expanded, perhaps rather more than a 1 per cent

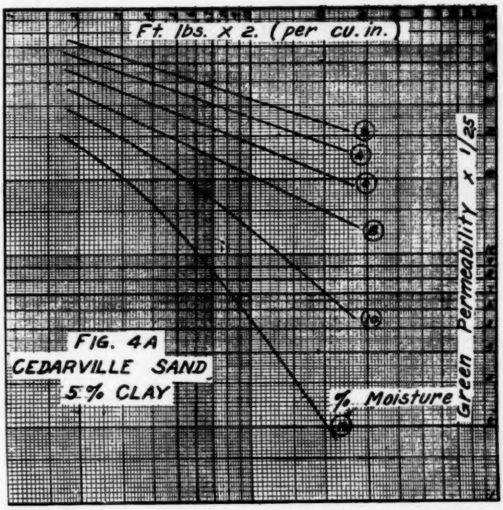


FIG. 4A—GREEN PERMEABILITY VERSUS RAMMING

increase in volume, with no indications that the changes were dependent upon moisture content.

The Permeability of Compacted Sands

Unless a sand is excessively wet, the permeability varies in simple exponential relation with the work done in compacting it.

$$\text{Log } P = A + B \text{ Log } W$$

where P is the permeability, A and B appropriate constants, and W is the work done on unit core volume.

When the sand is excessively wet, the permeability falls off more rapidly with increased ramming than the equation would require. This is fairly clear from Fig. 4 (ABC).

Curious relations are developed when permeabilities are

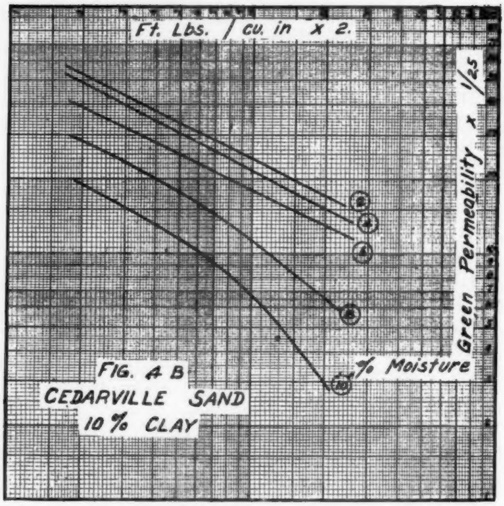


FIG. 4B—GREEN PERMEABILITY VERSUS RAMMING

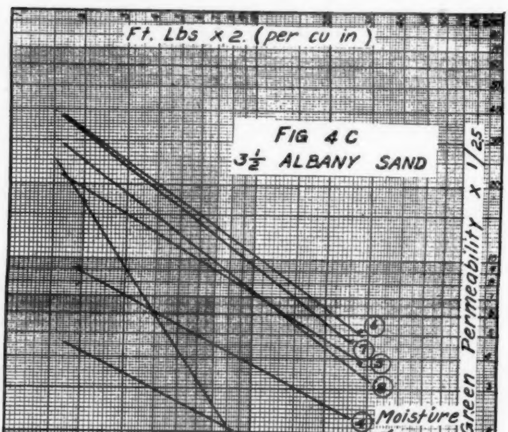


FIG. 4C—GREEN PERMEABILITY VERSUS RAMMING

plotted against the volume percentage of voids for the corresponding sands, as in Fig. 5 (ABC). Permeability is really an inverted measure of the frictional resistance offered by a core to the passage of air through it. Quite evidently, from Fig. 5, the frictional resistance offered by a dry sand grain surface is higher than that offered by a moist sand grain surface, hence, with a fixed voids ratio, the permeability increases with increasing moisture content. For equivalent ramming, however, the wetter sand will have less voids, so two opposed tendencies may sum

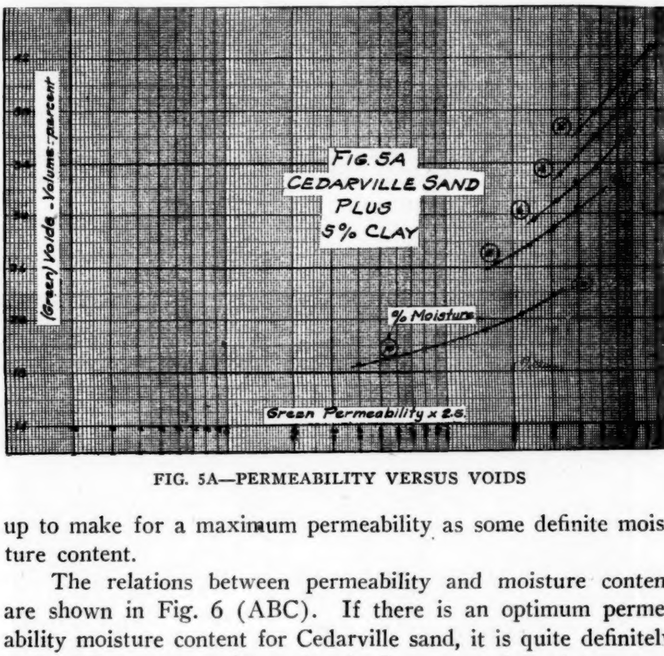


FIG. 5A—PERMEABILITY VERSUS VOIDS

up to make for a maximum permeability as some definite moisture content.

The relations between permeability and moisture content are shown in Fig. 6 (ABC). If there is an optimum permeability moisture content for Cedarville sand, it is quite definitelv under 1.9 per cent moisture for the 5 per cent clay mixture, and under 3 per cent for the 10 per cent clay mixture. These moistures are lower than any which would interest a foundry man. The Albany sand develops maximum permeability at about 6.5 per cent moisture.

The Cedarville sand mixtures are quite definitely wet—heavy

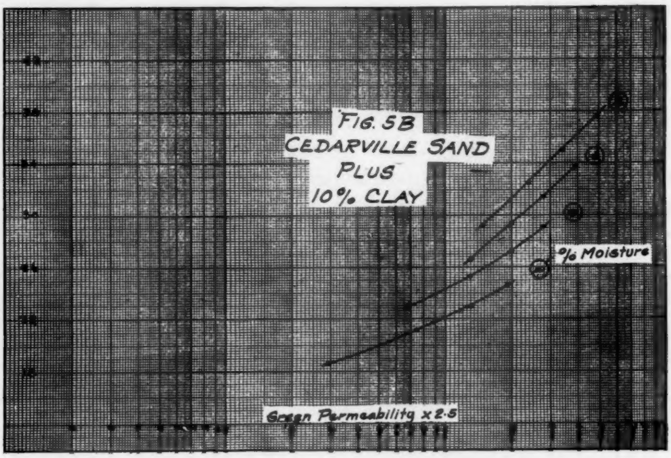


FIG. 5B—PERMEABILITY VERSUS VOIDS

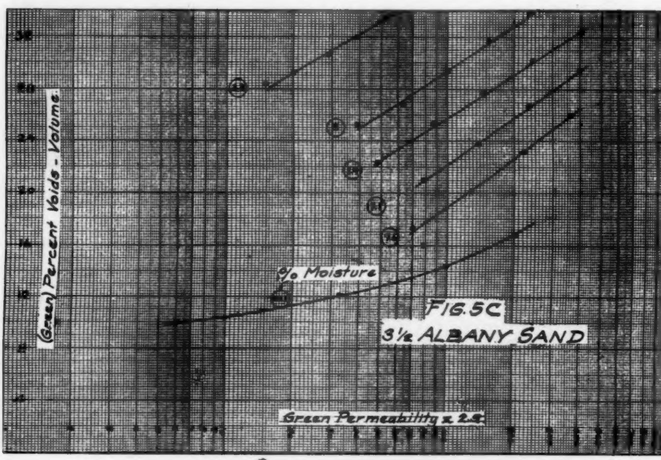


FIG. 5C—PERMEABILITY VERSUS VOIDS

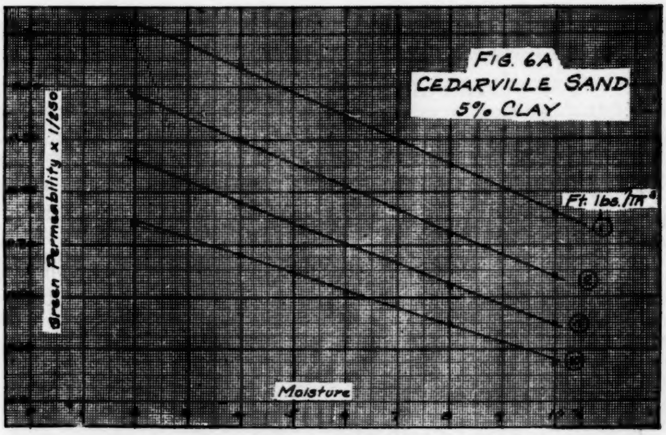


FIG. 6A—PERMEABILITY VERSUS MOISTURE

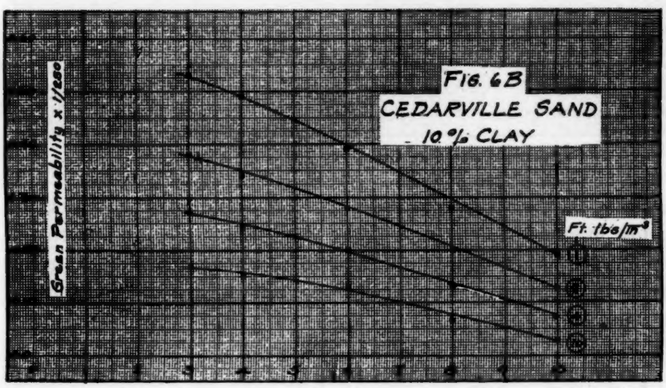


FIG. 6B—PERMEABILITY VERSUS MOISTURE

in the foundry man's language—when they contain in excess of 8 per cent moisture. The Albany sand is not definitely wet unless it contains more than 12 per cent moisture. At 8 per cent moisture, no sane foundry practice could possibly result in an impermeable mold with Cedarville sand containing 10 per cent clay. At 10 or 11 per cent moisture content the Albany sand

would be used by the molders without serious criticism and an impermeable mold could readily be made with it.

The Cohesive Strength of Compacted Sands

The green strength of a compacted sand varies with ramming in exactly the same manner as the density, as indicated in Fig. 7 (ABC). In fact, the green strength varies linearly with the green density so far as any given tempered sand mixture is concerned.

The relations between green strength and moisture content are shown in Fig. 8. Undoubtedly, the curves shown for Albany

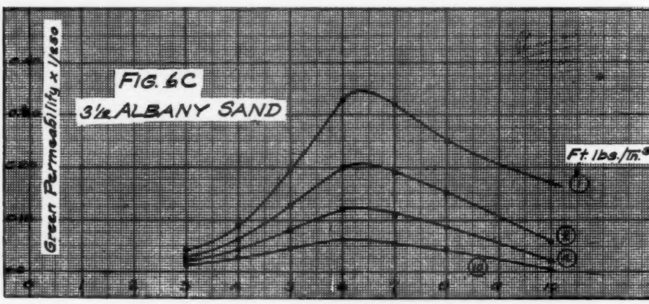


FIG. 6C—PERMEABILITY VERSUS MOISTURE

sand, with a definite optimum moisture content, are typical of sands in general but, again, the optimum moisture content at which the Cedarville sand mixtures develop maximum green strength are too near the bone dry condition to interest the foundry man.

The Green Compressive Strength of Compacted Sands

A complete series of green compressive strength determinations was made only with the Albany sand. The relations between strength and ramming, and the relations between strength and moisture content are shown in Fig. 9. A partially complete series of similar determinations were made with Cedarville sand plus 5 per cent clay, the results being given in Table 2.

In general, the compression test and the cohesiveness test relate green strength to moisture content in much the same

manner, but the inflection points in the strength-moisture curves are obtained quite consistently at lower moistures with the compression test than with the cohesiveness test. The writer is not clear as to whether this shift is a matter of testing methods or an actual difference between tensile and compressive strength.

Dry Crossbending Strength of Compacted Sands

The dry strength of a compacted sand varies linearly with logarithm of the work done in ramming and simply linearly with the dry density. This is shown in Figs. 10 (ABC) and 11 (ABC). Dry strength varies with the moisture content of the sand as molded as shown in Fig. 12 (ABC).

Fig. 12 (ABC) is of special interest when compared with Fig. 9 (ABC) since the comparison brings out the strong contrast between green and dry strength. A sand tempered for maximum green strength will develop scarcely measurable dry strength. This, of course, refers to clay bonded sands, but even sands bonded solely with oils, with flours, dextrin, glutrin, and the like, will develop immensely greater strength when molded wet than when molded at low to moderate moistures.

Fig. 11 (ABC) is also of special interest. The dry strength of a sand varies linearly with the dry density, but two variously tempered samples of the same mixture will not necessarily develop the same strength when compared at the same dry densities. The higher the moisture content, however, the more nearly does the strength-density relation become a specific one pertaining to the sand itself.

In general, when green and dry strengths are related to moisture content, it is found that the strength varies greatly with moisture content up to some fairly definite moisture limit. Beyond this limit the strength varies little with a further increase in moisture. The limit is undoubtedly the saturation point—where all of the sand grain surfaces are moist. Beyond the saturation point, as thus defined, the sand is unquestionably wet. Sand moistened beyond its saturation point develops dry strength proportionate to its final dry density. According to this manner of reasoning, the saturation point for Cedarville sand with 5 per cent clay is approximately 4 per cent moisture, for Cedar-

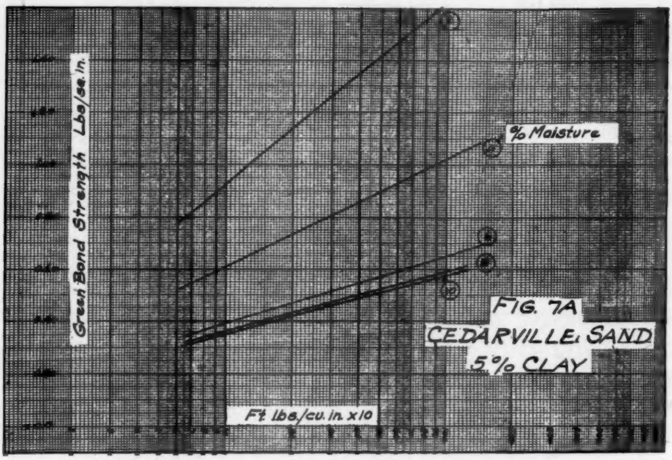


FIG. 7A—GREEN BOND STRENGTH VERSUS RAMMING

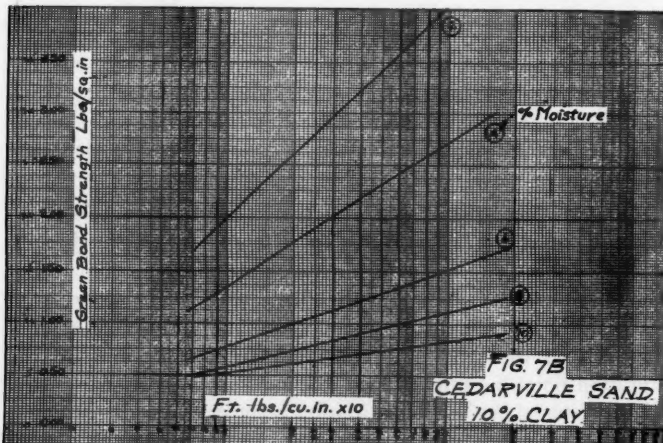


FIG. 7B—GREEN BOND STRENGTH VERSUS RAMMING

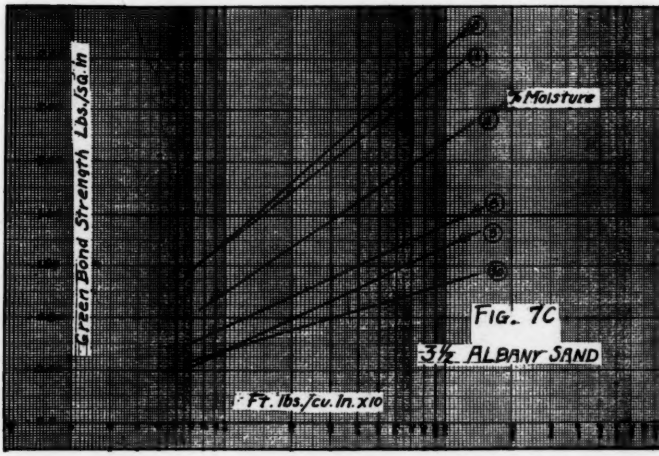


FIG. 7C—GREEN BOND STRENGTH VERSUS RAMMING

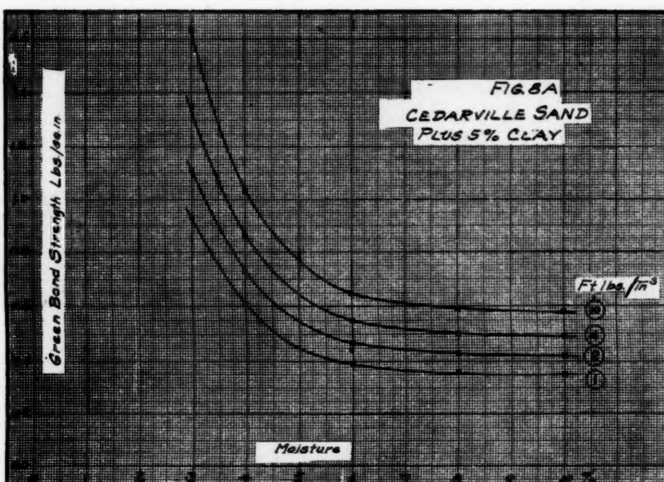


FIG. 8A—GREEN BOND STRENGTH VERSUS MOISTURE

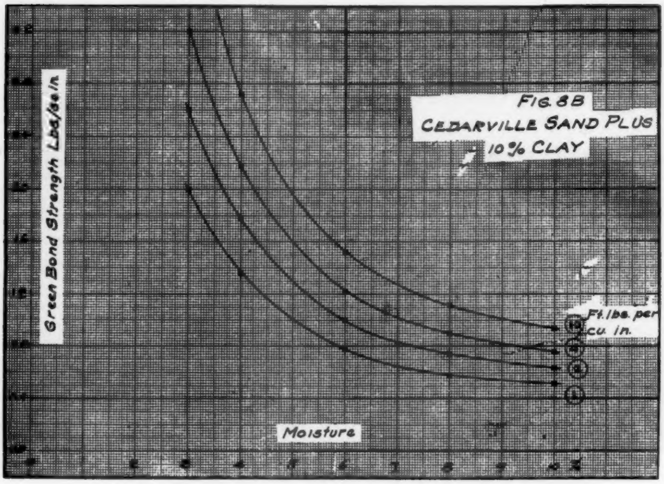


FIG. 8B—GREEN BOND STRENGTH VERSUS MOISTURE

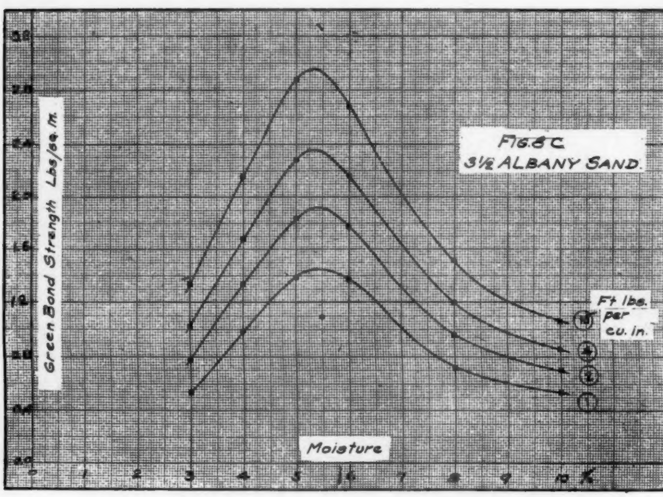


FIG. 8C—GREEN BOND STRENGTH VERSUS MOISTURE

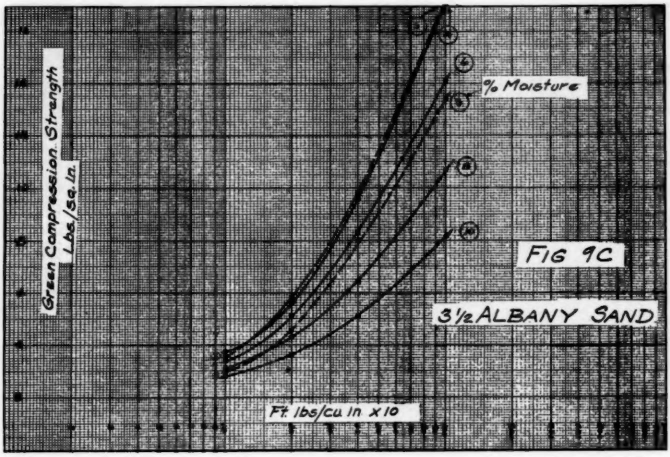


FIG. 9C—GREEN COMPRESSION STRENGTH VERSUS RAMMING

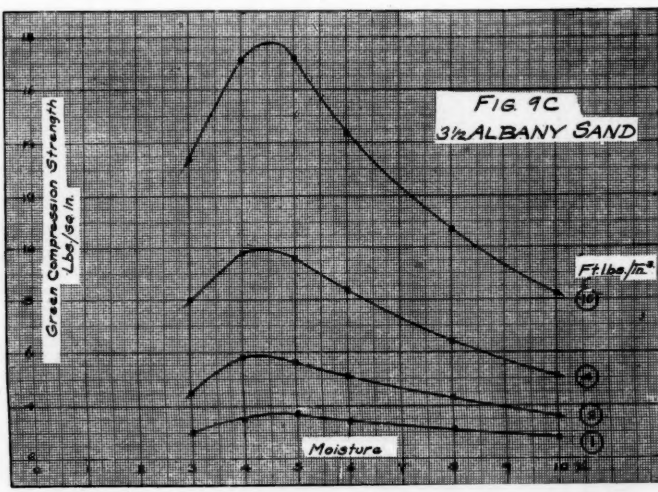


FIG. 9C—GREEN COMPRESSION STRENGTH VERSUS MOISTURE

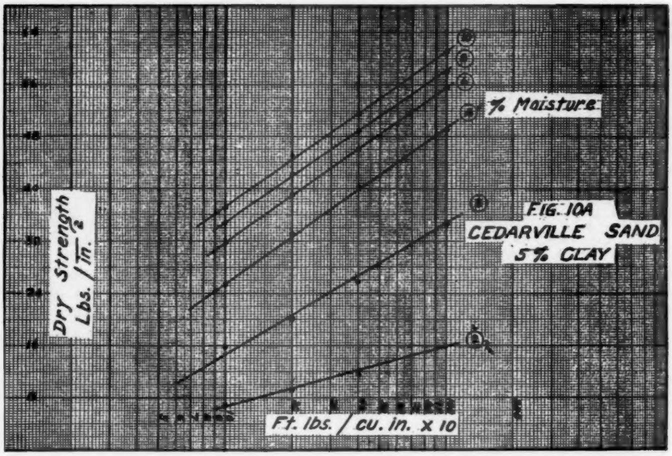


FIG. 10A—DRY CROSSBENDING STRENGTH VERSUS RAMMING

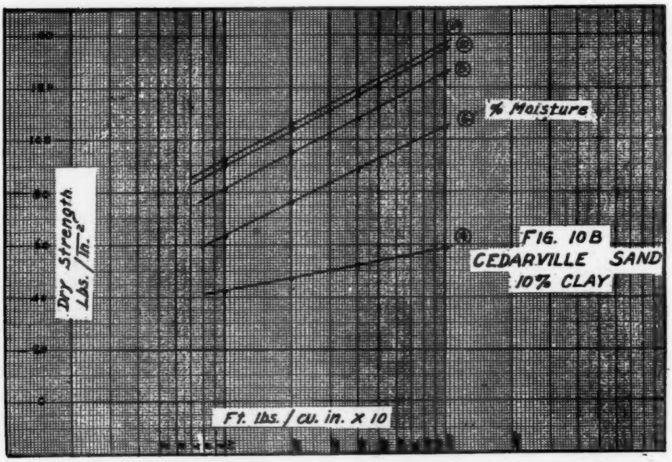


FIG. 10B—DRY CROSSBENDING STRENGTH VERSUS RAMMING

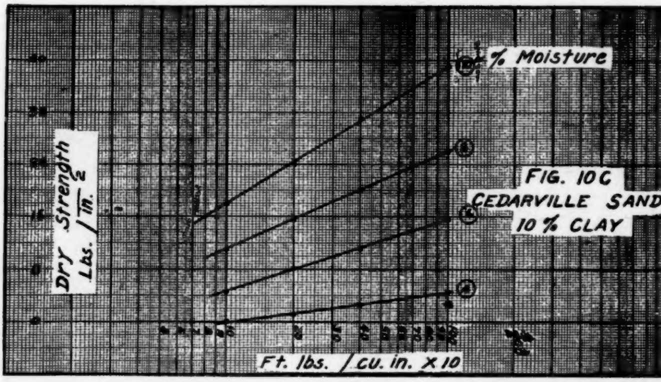


FIG. 10C—DRY CROSSBENDING STRENGTH VERSUS RAMMING

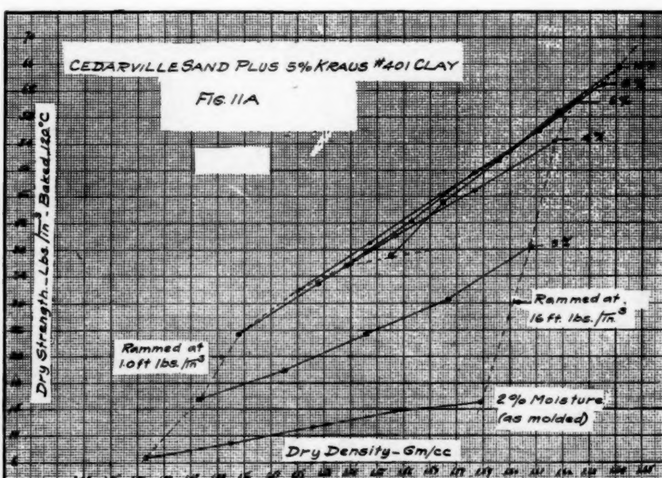


FIG. 11A—DRY CROSSBENDING STRENGTH VERSUS DRY DENSITY

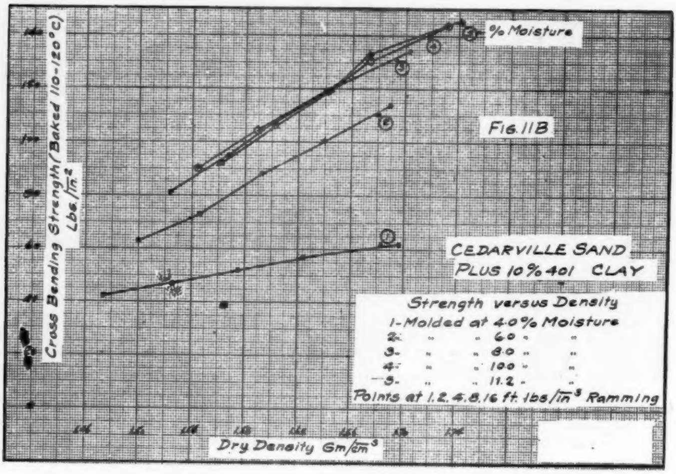


FIG. 11B—DRY CROSSBENDING STRENGTH VERSUS DRY DENSITY

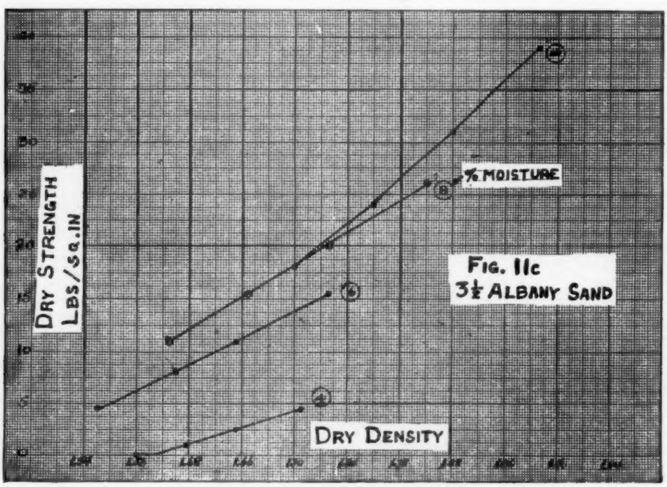


FIG. 11C—DRY CROSSBENDING STRENGTH VERSUS DRY DENSITY

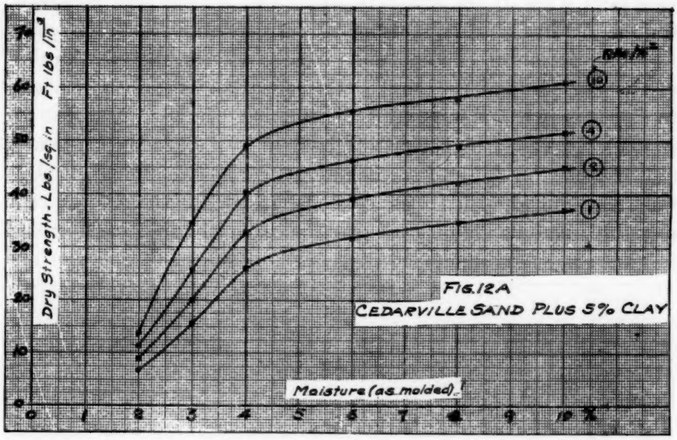


FIG. 12A—DRY CROSSBENDING STRENGTH VERSUS MOISTURE (AS MOLDED)

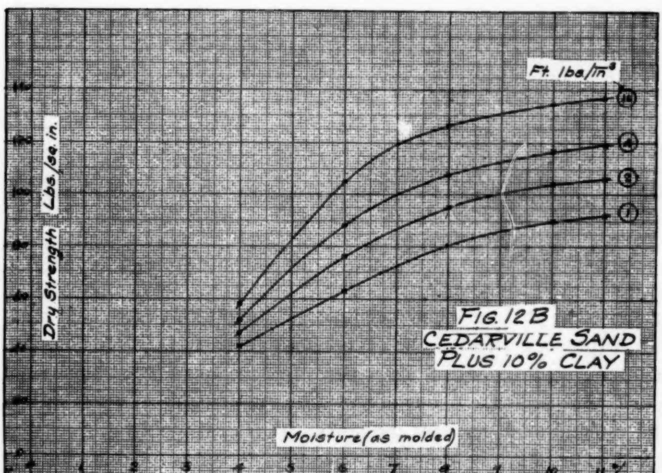


FIG. 12B—DRY CROSSBENDING STRENGTH VERSUS MOISTURE (AS MOLDED)

ville sand with 10 per cent clay it is about 6.5 per cent moisture, for the Albany sand it is above 10 per cent moisture.

The moisture content undoubtedly affects the distribution of the clay around the sand grains and the writer was curious to know in what manner this distribution of clay was affected. It might be that a high moisture content in the sand when it was milled made for a better distribution of clay in milling. Cedarville sand milled with 10 per cent water, dried back to 4 per cent moisture, and molded, developed the strength of a sand milled

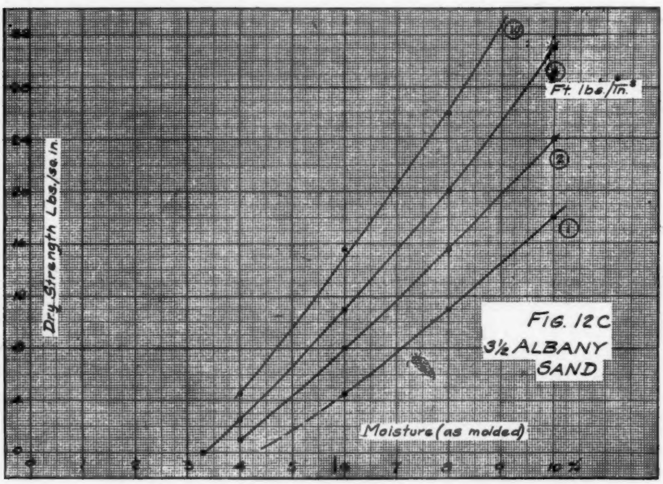


FIG. 12C—DRY CROSSBENDING STRENGTH VERSUS MOISTURE (AS MOLDED)

and molded at 4 per cent moisture. It might be that water present in the core affected the shrinkage of the clay. Cores molded at 4 per cent moisture, then permitted to absorb an additional 5 or 6 per cent water, developed the dry strength of cores milled and molded at 4 per cent moisture. It is reasonably certain that it is the moisture content in the sand when it is molded that determines the dry strength of the core.

A core molded at 4 per cent moisture, sprayed with water, and then slicked, developed more strength than a core merely

molded with 4 per cent moisture—quite evidently the slicked core possessed a greater surface strength than the comparison core.

The Dry Compressive Strength of Compacted Sands

As noted in the introduction, this testing method is in the course of development. A single series of tests applied to Albany sand were made by crushing dry cores in a 1,000 pound Riehle testing machine. The results obtained are shown in Fig. 13. The relations between green and dry crushing strength are evidently much the same as those between green cohesiveness and dry cross bending strength.

Too little has as yet been done with this testing method to make discussion of it profitable. It may be mentioned, however, that the dry crushing strength test has been found useful in exploring very weak sands, such as result from overbaking organically bonded cores or organically bonded cores which have been permitted to absorb moisture through their hygroscopic properties. The short, squat cylinder cores can be readily handled where the longer cross bending test cores cannot be picked up from the core plates.

Dry Strength and Baking Temperatures

The dry strengths heretofore considered were measured with cores baked more or less arbitrarily at 110 to 120 degrees Cent. Sands in the foundry are subjected to materially higher temperatures than this when metal is cast into sand molds. The value of such strength determinations may well be questioned.

Sharp sand cores bonded with linseed or tung oil and starch-dextrin binders serve regularly to give definite shape to very large steel castings. Cores bonded with linseed or tung oil almost completely lose their dry strength when heated to 230 to 250 degrees Cent. Starch-dextrin bonded cores, or for that matter cores bonded with any of the sugars, starches, gums, almost completely lose their dry strength when heated to 180 to 190 degrees Cent. The sand mold and cores serve as a container for molten metal; they abstract heat from the molten metal until the latter is solidified next the sand surface; after the casting has taken definite form it may in turn serve to advantage as a container for sand which has insufficient strength to hold

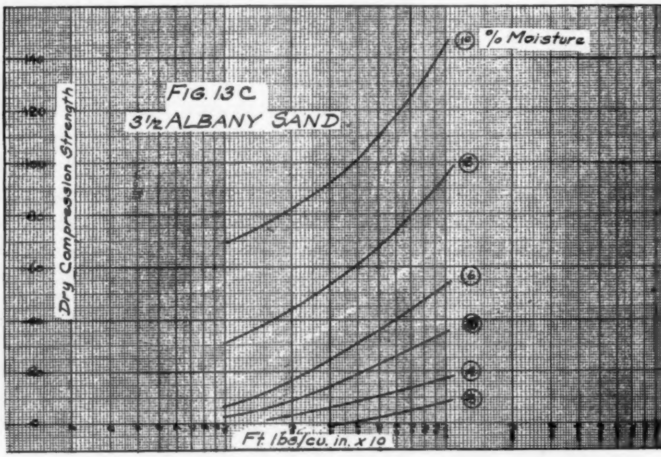


FIG. 13C—DRY COMPRESSION STRENGTH VERSUS RAMMING

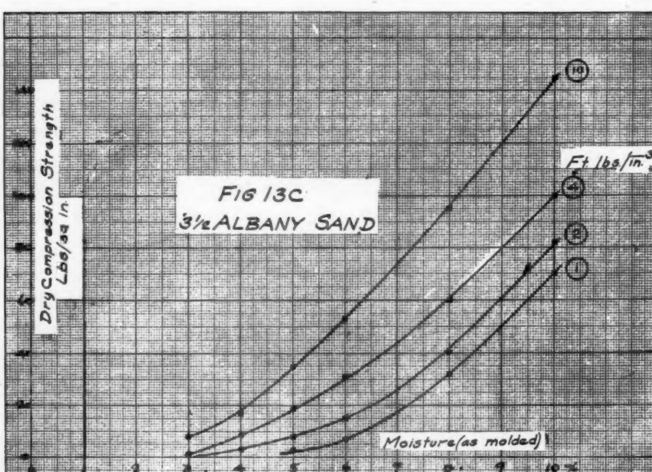


FIG. 13C—DRY COMPRESSION STRENGTH VERSUS MOISTURE

itself together. It is quite certain that only a very thin skin of sand is heated to as high a temperature as 200 degrees Cent., by the time a casting has assumed its form and final surface.

The behavior of clay bonded sands was studied in some detail in respect to baking temperatures. Cedarville sand to which 5 per cent of clay was added was molded at or above its saturation moisture content and the resulting cores were variously heated at 130, 180, 300 and 600 degrees Cent. All of the cores except the last were heated overnight at the temperatures indicated; the exceptions were heated overnight at 130 degrees Cent. and held at 600 degrees Cent. for 2 hours.

The comparative tests were made with a half dozen clays which happened to be available in the laboratory. The results are indicated in Table 3 and somewhat idealized in Fig. 14.

Table 3

Dry Strength—Cedarville Sand Plus 5 Per Cent Clay

Clay	Per cent moisture in sand as molded	Dry strength when baked at temperature indicated, degrees Cent. 130	180	300	600
Brammell No. 15, Enid, Miss.	7.8	47.3	40.3	28.9	8.8
Kraus No. 401	7.5	52.0	49.7	34.1	16.2
LaClede Christie, St. Louis	8.4	31.3	29.6	25.6	20.9
Dixon Crucible Co.	7.7	42.0	36.0	29.0	24.0
Jersey Red	8.5	17.1	14.0	12.7	8.0
Jersey Buff	7.8	23.7	20.0	16.0	13.9
Local (Schenectady)	7.9	21.8	15.1	14.9	12.1

The most plastic of the clays, Kraus No. 401 and Brammell No. 15, lose strength more rapidly with increasing temperature than do the less plastic clays, and clay bonded cores heated to 300 degrees Cent., then remilled and reformed into cores do not develop their original strength, the more plastic clays deteriorating proportionately more than the less plastic clays.

Insufficient work along this line has been done, and the above data are considered merely suggestive. It appears certain that the determination of strength of clay bonded sands heated to 100 to 120 degrees Cent. determines as well the order of the strength at such temperatures as concern us in giving form to castings.

The deterioration of clays is another matter with which the writer is not here concerned; it has its bearing on the "life" of molding sands.

Discussion

The writer undertook comparative studies of sands in the manner indicated in the hope of being able to answer to his own satisfaction several puzzling questions which have been answered and explained in numerous publications and in numerous contradictory ways or in ways that will not stand even casual experimental analysis. He frankly admits that he is still unable to answer most of these questions in a manner that carries complete conviction to himself. The following discussion is then largely speculation based upon efforts to find something better

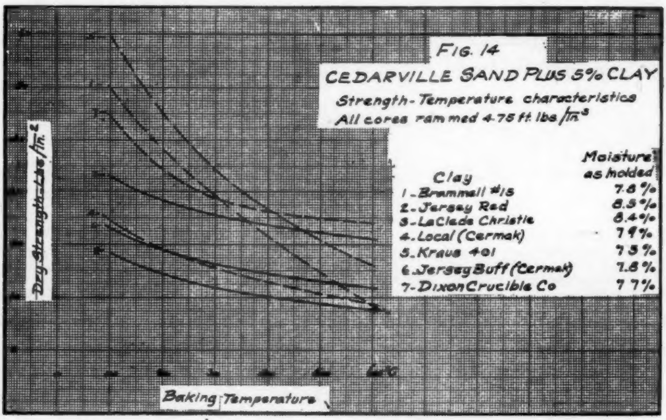


FIG. 14—DRY STRENGTH VERSUS BAKING TEMPERATURE

than a speculative answer, and it is put forward primarily to stimulate interest in obtaining something better than speculative answers. The discussion has a secondary purpose of discouraging an unwarranted enthusiasm in collecting unrelated data on foundry sands—data which are quite as likely to lead to faulty conclusions as to improved foundry practice.

The questions referred to, and the answers they require, are more or less inextricably inter-related, so that it is difficult to consider them in logical sequence. The writer therefore begs indulgence if the discussion becomes somewhat incoherent.

All foundry sands are tempered with water, and the meas-

urable properties of two variously tempered samples of the same sand may readily differ more than those of two distinctly different sands. An effort was made to find laws relating two or more properties of a sand, in the hope that the constants which would give mathematical expression to these laws would be specific for the sand more or less independent of its moisture content. This hope has found little to feed upon. Simple relations have been found to exist between many of the measurable properties of a specific tempered sand but, again, the constants for the equations developed differ more as between two variously tempered samples of the same sand than they necessarily do as between two distinctly different sands. It does appear that the amount of dry sand that will crowd into a given volume, the dry density calculated from the green density, when a sand is moistened and heavily rammed, is a fairly specific property of the sand. The higher this density, the greater the non-uniformity of grain size and the lower the permeability are likely to be—but this might better be judged from a screen analysis. The relation between dry strength and dry density for reasonably tempered sands appears to be specific sand property but a determined point does not define a line, so a reported dry strength value requires qualification.

If testing methods cannot be developed that render the results independent of the moisture in the sand tested, is there a simple and rapid method of determining at what moisture content a sand should be tested so that proper comparisons of sands can be made? Authoritative recommendations have been made; a sand should be tempered in such manner as to bring out its maximum green strength and its maximum permeability. If the proper amount of moisture necessary to serve this purpose is not known, the sand should be tempered with 4, 6, and 8 per cent moisture and tested at each of these tempers. Unauthoritative recommendations have been made repeatedly that sands intended for dry sand molds should be tempered with a minimum of water, since the expulsion of the moisture in drying ovens is expensive.

Curiously enough, the first sand to which the writer attempted to apply these recommendations, Cedarville sand plus clay, failed to develop the identifying humps in the green

strength-moisture and permeability-moisture curves. The drier the sand the higher was the green strength and the higher the permeability. This was followed down the scale of decreasing moistures until the green test core surfaces spawled away as they air dried. In the meantime Cedarville sand was being regularly used as an oil bound core sand tempered with 10 per cent or more moisture and it made exceptionally satisfactory cores in both iron and steel foundries. Cedarville sand bonded with a moderate amount of clay was also being fairly successfully used as a steel mold facing—both dry and green sand molds. For this purpose it was tempered with an average of 6.5 per cent moisture. If the moisture dropped to 4 per cent, the molds would not withstand the action of molten metal; the castings were scabbed and dirty. Three distinct recommendations regarding proper temper certainly did not apply to Cedarville sand, and it has later appeared that most reasonably uniform grained sands are equally exceptions that prove the value of rules and recommendations.

There is still the recommendation that a sand be tested at 4, 6 and 8 per cent moisture. During certain seasons, perhaps every foundry is required to select the sands that shall be purchased for use during the following year. A hit and miss trial of the various sands offered, whether in the foundry or in the laboratory, is certainly an unsatisfactory basis for selecting one or more of them. An elaborate series of tests in the foundry is practically out of the question because of the time required to make the tests conclusive—if not because of the disorganization the testing involves. Laboratory tests cannot well be made conclusive, but they should be developable to a point where they can properly serve to weed out a lot of trash and to select from the many a few that are worthy of conscientious study in the foundry. The mere determination of fineness, of clay content, and of the green strength and permeability of sands tempered to 4, 6, and 8 per cent moisture does not seriously cramp a free hand style of making comparisons or of drawing conclusions.

Again, why should one determine the green strength of sands with cores more heavily rammed than characterizes moderately heavy ramming in practical foundry work, when it is fairly

common knowledge that it is the too lightly rammed portions of a cope that drop? Why should one determine permeability with very lightly rammed cores, when it is fairly common knowledge that it is too heavily rammed sands that blow? These are not to be taken as invidious criticisms.

It seems to the writer that the problems involved in the selection and control of foundry sands are essentially deeper than an inexperienced person of average intelligence may legitimately assume them to be after a careful survey of such information as he can find in the available foundry literature. It is not so much a matter of ascertaining the specific green strength of a specific sand as it is of finding out what green strength determinations mean, and what their significance is in relation to the making of castings.

What Is Green Strength?

What, for example, is green strength, and what is its significance in relation to the making of castings? In the writer's present opinion, and his opinions have changed so frequently during the past year that the adjective is advisedly used, green strength is almost purely a matter of the surface tension of the water held between the grains of a compacted sand. The figures obtained for cohesiveness and green compression strength are primarily a measure of the new water surface created in order to accommodate a displacement of the sand grains when a core is ruptured. Dry sand grains are not held together for lack of a liquid, the sand is mobile but has no green strength. A quick sand, essentially any sand with the interstices between grains completely filled with water, is mobile and has no green strength because the sand grains can move freely without altering the water surface exposed. As moisture is added to a dry sand the green strength should increase to some maximum value that should be a fairly specific property of the sand; the finer the sand grains and the closer they are compacted, the smaller should be the interstices between grains, the more tenaciously should water be held (as in capillaries), and the greater should be the maximum green bond strength. The addition of further moisture should permit a freer movement of the sand grains until ultimately the sand becomes a true quick sand. If this view

is correct, then the effort required to remove water from a tempered sand should be related simply to surface tension and to green strength. A tentative exploration into this field was made with a centrifuge—a very poorly adapted one—the Rotarex machine. The data obtained are set forth in Table 4.

Table 4

Rotarex machine Rpm.	a/g	Grams moisture retained per 100 gm. dry sand after 10 minutes' rotation
0 (drained on filter)	1	19.1
210	5.1	16.3
360	14.9	13.5
510	29.8	8.1
1000	116	7.2
2000	464	6.05
2500	724	5.7

In this table, a/g is the apparent weight of a pound of water at the mean radius of gyration at the rotational speed indicated. When the gravitational effort a/g is plotted against residual moisture, it is found that a simple exponential relation exists through the range 5.7 to something less than 8.0 per cent moisture, and that there is a sharp discontinuity near 8.0 per cent moisture. Moisture in excess of 8 per cent is not held very tenaciously. On the decreasing moisture scale, each unit of water below 8 per cent is held with increasing tenacity. The saturation point for this particular sand is not far from the 8 per cent critical point above. The green strength increases rapidly as the moisture falls below the saturation point.

Surface tension forces are adequate to account for the observed character of green strength in sands but this is not the whole story.

Mechanical Tests Versus Practical Judgment

If a series of clay bonded sands be tested for green strength, and an experienced foundry man is asked to place the sands in the relative order of their green strength, he readily does place them in the same order as the cohesiveness test and green compression test. If a few lots of sand containing flour, starch, dextrin, and the like be sandwiched in between the clay bonded sands, the foundry man and the green strength tests are no longer in even approximate agreement. According to the foundry man, flour, starch, etc., add to the green bond strength.

According to the green strength tests, few of the organic binders add appreciably to the green strength, and many of them actually decrease it. Another factor has crept into the game that the tests ignore—the viscosity or mobility of the sand. The surface tension of a 10 per cent starch solution is probably not very different from that of pure water, but the starch solution is a very stiff jelly. Possibly the jelly will rise about as far in a given capillary as will pure water, but the jelly will certainly not rise as rapidly as the water; the jelly is extremely viscous.

Cedarville sand bonded with pure water develops practically the same green strength as does Cedarville sand bonded with a 10 per cent starch jelly, but the two sands differ greatly in appearance and "feel" and they differ materially in the manner in which they fail in test. The water bonded sand will carry a little less than the breaking load indefinitely and it will fail sharply and completely when the breaking load is applied. The starch bonded sand in compression will momentarily carry a little more than the breaking load but the core slowly flattens out into a more or less coherent pancake. In the cohesiveness test, the starch bonded core sags over the edge of the supporting plate. Heavily clay bonded cores act somewhat like starch bonded cores over certain moisture ranges.

Herein lies the probable explanation of the difference in the relative order of "green strength" in which the foundry man and the laboratory tests will place a series of sands. The explanation offered has not been systematically tested since the writer has not found a suitable method of making such tests quantitative. The starch bonded sand is more viscous, less mobile, less fluid, than the water bonded sand. Viscosity does not enter directly in determining green strength, but the density of the compacted sand does, and the viscosity can have a very direct bearing upon the density of the compacted sand depending upon the manner in which the sand is rammed. In all of the laboratory tests, the cores are so compacted that the sand is confined by the core box and ramming head; all of the sand is directly in the line of the ramming effort; and little or no lateral displacement of the sand is required in order that the sand shall be uniformly compacted. This is not the condition that maintains in

an average core box nor in a moderately intricate mold. The mobile sand does not seriously resist lateral displacement; it will flow laterally under the rammer head when the latter does not serve to confine all of the sand in the core box; it will flow sidewise until stopped by a vertical surface; it will flow into a deep pocket in a pattern; but it cannot be tightly rammed unless confined by the rammer. The viscous sand resists lateral displacement by reason of its viscosity; it can readily lead to the formation of compressed sand stilts beneath a rammer head—by reason of the time element of flow involved. It can be tightly rammed, but it must be tightly rammed against a vertical surface if it is to be compacted next that surface; it will tend to jamb at the throat of a deep pocket in a pattern. This is of more than merely academic interest, as the most casual inspection of molds in an average foundry will indicate. Loosely rammed projections, edges, fillets are fairly common, particularly where low moisture sands are used. Rough surfaces and sand inclusions are common in the castings made from such molds.

Compressed sand stilts can readily be formed under the rammer head when a viscous sand is used. Suppose that a pattern of such stilts is made in a mold by moving about a pneumatic rammer. If one unit of work is required to compress a sand a certain small fraction of its volume, be this unit 0.1 or 1 or 10 foot pounds, it will require 10 work units of work, be it 1 or 10 or 100 foot pounds, to compress the sand an equal additional fraction; the compressed sand stilts must be pounded down in order to get at the loosely compressed sand between the stilts.

Now it is rather idle to discuss further the specific relations between viscosity and moisture, as distinct from the relations between green strength and moisture, without data bearing definitely on the viscosity factor. But a clay certainly is most viscous when it contains but a moderate amount of water, and it becomes less viscous as more water is added; a heavily clay bonded sand rolls up into pellets in a mill when moderately moistened and it is exceedingly difficult to flatten out the pellets against a smooth pattern surface.

It seems fairly certain that the viscosity of a sand varies in relation to moisture content in somewhat the manner in which

green strength varies; high green strength more or less connotes a high viscosity, and a low green strength connotes a reasonably low viscosity or fairly high mobility.

It is also reasonably certain that green strength (coupled with viscosity, of which we know too little) determines the moldability of a sand—but in a sense that a high green strength rather militates against a uniformly compacted mold.

Green Strength Versus Capacity of Mold to Withstand Action of Molten Metal

But has green strength any bearing upon the capacity of a mold to withstand the action of molten metal? Cedarville sand tempered with pure water develops sufficient green strength so that it can be molded, but a casting cannot be made in the resulting mold because the sand collapses before the casting will take shape. Are not all sand molds dry sand molds in the sense that the sand surface next the pattern is certainly skin dried by the incoming metal before the mold is filled and long before the casting has acquired its final form and curface? If green strength is due purely to the surface tension of the water or aqueous solutions of binder in the compacted sand, it does not seem possible that it can have a direct bearing upon the action of the molten metal on the skin dried mold surface which gives shape to the casting.

The "life" of a molding sand can be burnt out of it without greatly affecting its green strength on retempering; the burnt sand develops no dry strength when the retempered cores are baked. Cedarville sand and clay mixtures, tempered well below the saturation point, develop much more green strength than is necessary for molding purposes; the molds do not withstand the action of molten steel; the sand so tempered develops almost no dry strength. The same mixtures tempered well up around the saturation point develop very much less green strength; they withstand the action of molten steel exceptionally well; the sand so tempered develops a fairly high dry strength.

It surely cannot be a mere coincidence that for a dozen sands that have been tested in more or less the manner previously discussed, the same relations between green strength and dry strength have been found to exist; the dry strength ap-

proaches zero as the green strength approaches its maximum—on a decreasing moisture scale. It is not likely to be a mere coincidence either, that when experienced foundry men were asked to temper this dozen sands, they did temper by "feel" to a point reasonably close to the saturation limit—well down in the belly of the curves in Figure 8—and by no means close to the point of maximum green strength. The writer is concerned primarily with dry and green sands used in the making of very large iron and steel castings, with molds that may be a day, a month, or even two months in preparation. He has collected some little information, but too little to make discussion of it profitable, which indicates that the same reasoning applies to small brass foundry bench molds.

Perhaps this answers the question of the proper temper at which to use a molding sand, or, at any rate, the proper temper at which to use a facing sand. At any rate, the writer prefers to temper a sand for test purposes at as near as may be to the saturation point, and to include in his tests such information on the dry strength of the sand as can conveniently be determined.

Until sufficient data have been collected to make generalizations safe, he prefers to determine the properties of both lightly and heavily rammed sands, and if time is not available in which to do this he inclines to prefer testing for strength on lightly rammed sands and for permeability on heavily rammed sands. This last, of course, is on the principle that it is best to know how badly a sand can behave.

In mixing sands, the evidence conveyed by density and permeability determinations strongly indicates the futility of attempting to open up a close sand by admixing a coarse sand. The more uniform a sand is in grain size, the more nearly fool proof it is, and if it requires admixtures it seems desirable to select the admixture to secure as nearly the same grain sizes in all of the sand components of the mixture.

Dry strength may be obtained by molding heavily clay bonded sands at relatively low moistures or by molding moderately low clay content sands at relatively high moistures. The low clay-high moisture sands are decidedly to be preferred as being the more fool proof; molds may be lost in the making be-

cause such sands have little green strength, but it is better to lose a mold than to make the mold and lose the casting.

In dry sand molding, considerably more dry strength is necessary in order that a mold shall withstand rough handling in and out of the drying ovens and in assembly, than is necessary merely to withstand the action of molten metal. In this case it seems preferable to use clay sufficient to give that portion of the strength which controls the action of the metal upon the mold, and to add the insurance against rough handling by using organic binders. The latter should be used sparingly—less than one-half per cent by weight for the usual variety of starches, sugars, and gums—for an injudicious extravagance in the use of these binders can readily lead to crushing strengths exceeding those of excellent concrete.

A Study of Molding Sand Mixtures and the Molds and Castings Produced Therefrom

By R. F. Harrington, A. S. Wright and W. L. MacComb, Boston, Mass.

For a considerable period of time, data in relation to the permeability, dye adsorption value, clay substance, cohesiveness, mechanical analyses and grain structure on our various molding sand heaps have been maintained for the purpose of scientifically controlling these heaps. Their value in keeping down defective castings and in cutting down new material can not, in our opinion, be disputed.

In addition to the control work, tests were made to ascertain the quality of castings which could be produced when sands of different moisture content, grain structure, clay substance, permeability, and cohesiveness and dye adsorption properties were used.

These data were gathered, with a view to improving our present practice and of obtaining information which we later anticipated, would be useful in our research work on semi-synthetic and synthetic sands.

Our experience has made us realize more than ever the magnitude of the problem.

From this experience there seems to be many phases of the molding sand question to which the progressive foundryman must give his attention if he expects to eliminate the many kinks which seem to be inherent in it.

One of the most important of these, in our opinion, is that of permeability which is, of course, dependent upon the factors enumerated above.

Foundryman Must Know Permeability Factors

Hence the foundryman must be familiar with and know the approximate effect of the various elements which are the determining factors in producing the permeability. Knowing the

above, he is able to deliver to the molder from day to day a sand of uniform properties.

He must also know how the venting properties of a mold itself are affected by the manner and extent of ramming. The individual who desires to keep the venting properties of the mold under rigid scientific control cannot expect to believe that his job is completed when the sand which is delivered on the foundry floor from day to day shows no variation in permeability and the other elements under consideration.

One can readily conceive of two molding sands of widely different permeability which when subjected to different conditions of ramming produce molds of equal venting properties or vice versa, two sands of equal permeability which when subjected to different conditions of ramming will produce molds of wide variation in venting properties.

Recent investigation has demonstrated beyond any questioning that the manner in which the sand is rammed is of very great importance.

In order to give a daily check upon the molds as produced from various patterns in different divisions of the shop and under different jolting conditions, a machine was purchased which has served to give some additional knowledge as to the condition of the mold, in regard to its permeability.

Permeability Apparatus Used

The principle of the apparatus used for testing the molds is described below.

This apparatus consists of a small positive pressure blower driven directly by an electric motor. The air passes from the blower to a manometer and thence through a piece of flexible rubber tubing to the surface to be tested. The manometer is mounted in a vertical position and graduated from 0 to 100 per cent. As the column of air enters the cell of the manometer it is split in three ways; 1—pressure area; 2—overflow; and 3—test current. With the opening which comes into immediate contact with the mold closed, we can, by adjusting the valves at the manometer, so regulate the flow of air that a pressure reading of 0 per cent will be recorded.

Now in order to test the molds we place the current of air in contact with the surface of the mold to be tested. If the mold is relatively open the flow of air will not be retarded as much as though the same mold were made from a much finer sand and was consequently more dense. The extent to which the flow is retarded is measured on the manometer scale, as previously stated, and may vary from 0 per cent, in which case none of the air can pass through the mold, to 100 per cent with no resistance to the flow.

In practice we found that a mold which, according to our standards was sufficiently permeable, would give a reading of 55 to 60 per cent on this machine, whereas from a mold made from fine sand, or a sand of too high clay content and from which, due to its nature we expected to obtain scabby castings, a reading from 20 to 30 per cent was obtained.

As indicating the effect of various number of jolts on the same sand, there are enumerated in Table 1 values which are self-explanatory.

Table 1

Mold Readings

Jolts No.	Core Top	Core Middle	Core Bottom	Cheek Top	Cheek Middle	Cheek Bottom
	Per Cent Permeable			Per Cent Permeable		
140........	38	36	40	43	45	46
140........	40	41	44	44	48	48
140........	33	38	39	40	41	43
75........	57	53	53	61	61	60
75........	48	46	47	57	52	54
75........	51	47	55	61	61	59
50........	62	59	61	59	56	59
50........	56	59	62	65	68	71
50........	61	62	63	67	67	63

Our mechanical department which is responsible for the condition of jolting machine equipment has found great value in the data obtained on the mold as an indication of the mechanical operation of the machine. That is to say, if over a period of time molding sands of definite permeability give definite mold permeabilities under a definite number of jolts, if with the sand permeability constant and the number of jolts

constant there is a variation in mold permeability, we can very properly look to the condition of the machine which may be responsible for the changed condition on the mold due to improper cushioning of the blow with consequently varying effects.

Thus we have a further practical application of mold permeability testing.

In our effort to better mold conditions and to obtain better ultimate castings at a less cost, different molding sands and materials were employed having the desired physical characteristics. These variations were accomplished either by proportioning the percentages of the different elements entering the same or by some external means such as the manner of preparation or mixing. Molds were made from these sands and the rough castings produced were subjected to a very careful examination. Great care was especially taken to notice the extent to which the sand had fused to casting, soundness and the general appearance of same. The castings were then machined under observation and examined for the various defects which are characteristic of this particular type of casting.

Many of the details entering into the molding practice, such as location, inclination, number, size and character of sprues used, manner of ramming, reaming and butting of sprue holes, time of pouring, slicking and leading of the mold, and other practices were studied.

In all work of this kind it is obviously necessary to obtain as much information and data as possible. In order that the foundryman may have a clear conception as to the thoroughness with which we believe this work should be undertaken, blank forms are filled in listing the information given under Form 1.

Form 1
(Unfilled)

SAND TESTING LABORATORY

Report of Castings Made From Special Sands

Type of Castings **Patt. No.** **Casing No.**

1. COMPOSITION OF MOLD

A. ....
B. ....
C. ....
D. ....
E. . . Final Molding Material..................................

Form 1—(*Continued*)

ANALYSIS

	A	B	C	D	E
Per Cent Clay	......	......	......	......	......
Retained on 6 Mesh......	......	......	......	......	......
Retained on 12 Mesh......	......	......	......	......	......
Retained on 20 Mesh......	......	......	......	......	......
Retained on 40 Mesh......	......	......	......	......	......
Retained on 70 Mesh......	......	......	......	......	......
Retained on 100 Mesh......	......	......	......	......	......
Retained on 140 Mesh......	......	......	......	......	......
Retained on 200 Mesh......	......	......	......	......	......
Retained on 270 Mesh......	......	......	......	......	......
Through 270 Mesh......	......	......	......	......	......
Total	......	......	......	......	......
Permeability	......	......	......	......	......
Per Cent Moisture	......	......	......	......	......
Dye Adsorption No........	......	......	......	......	......
Cohesiveness	......	......	......	......	......
Fusion Point	......	......	......	......	......

2. METHOD OF MIXING

3. METHOD OF MOLDING AND REMARKS No. of Jolts

4. STUDY OF MOLD

PERMEABILITY MOLD VALUES

	Values on Cars	Average	Grand. Av.
Top	....	....	....
Middle	....	....	....
Bottom	....	....	....
	Values on Cheek	**Average**	**Grand. Av.**
Top	....	....	....
Middle	....	....	....
Bottom	....	....	....
	Values on Cope		**Average**

5. STUDY OF ROUGH CASTINGS AND SPRUES

Temperature poured ....

Time of pouring..

Weight of rough casting......................................

Sponge	Buckled	Sand Holes ....
Slag	Scab	Swell ....
Crush	Shrink	Lugs Blown..........
Mold Blown	Gas Holes	Lugs Strained........
Hard		

General Remarks: ....

6. STUDY OF STRAIN

7. STUDY OF MACHINED CASTING

8. RECLAIMED SAND

A. Mixture of all sand taken from flask........................

B. Fused portion of the sand...................................

C. Portion not fused...

D. ....

Form 1—*(Continued)*

ANALYSIS

	A	B	C	D	
Per Cent Clay	......	......	......	......	......
Retained on 6 Mesh......	......	......	......	......	......
Retained on 12 Mesh......	......	......	......	......	......
Retained on 20 Mesh......	......	......	......	......	......
Retained on 40 Mesh......	......	......	......	......	......
Retained on 70 Mesh......	......	......	......	......	......
Retained on 100 Mesh......	......	......	......	......	......
Retained on 140 Mesh......	......	......	......	......	......
Retained on 200 Mesh......	......	......	......	......	......
Retained on 270 Mesh......	......	......	......	......	......
Through 270 Mesh......	......	......	......	......	......
Total	......	......	......	......	......
Permeability	......	......	......	......	......
Per Cent Moisture	......	......	......	......	......
Dye Adsorption No........	......	......	......	......	......
Cohesiveness	......	......	......	......	......
Fusion Point	......	......	......	......	......

9. GENERAL DISCUSSION OF TESTS

Sample of Information Listed on Blank Forms

Below is a typical resumé of one of these reports.

FORM 1 FILLED OUT

Purpose:—To produce a mold and satisfactory casting from reclaimed burnt sand and reclaimed clay substance.

Material Used:

Grains reclaimed from burnt sand.....	50 per cent
Clay reclaimed from burnt sand.......	7.1 per cent
Grains separated from new sand......	39.7 per cent
Clay separated from new sand........	3.2 per cent
Total	100.0 per cent

Method of Mixing:

Grains moistened and mixed by shovel previous to any additions of clay. Clay distributed uniformly and worked through grains by shoveling and hand mulling.

Analysis of Sand:

Clay Substance.........................	9.8 per cent
Retained on 6 mesh	3.5 per cent
Retained on 12 mesh	8.7 per cent

Retained on 20 mesh	27.4 per cent
Retained on 40 mesh	29.4 per cent
Retained on 70 mesh	14.9 per cent
Retained on 100 mesh	1.6 per cent
Retained on 140 mesh	1.0 per cent
Retained on 200 mesh	0.7 per cent
Retained on 270 mesh	0.5 per cent
Through 270 mesh	2.1 per cent
Permeability	737
Moisture	7.4 per cent
Dye Adsorption Value	548

Method of Molding and Remarks:

Machine jolted and well leaded. No seacoal was added to the mix. Sand felt good, tooled well, rammed firmly and took a heavy coating of lead.

Appearance of Casting:

Equally as good as similar castings made from regular heap sand. Sand did not fuse to casting to any appreciable extent. Absence of sand washing observed during machining operation. No defects on either outer or inner surfaces of finished casting.

General Discussion.

1. Based upon general appearances and feel this sand possessed all the properties of a good molding sand.

2. The very noticeable difference in permeability between this prepared sand and a sand of similar mechanical analysis and clay content must be attributed to the method of mixing; this sand having a permeability value of 737 with 7.4 per cent of water, whereas a comparable foundry sand carrying that quantity of water would not have a permeability value exceeding 250. A more uniform distribution of the clay and grain, with the resultant elimination of fines and closed voids, must be accomplished by this method of mixing.

3. A clay substance of 9.8 per cent and a dye adsorption value of 548 in the original sand, as compared with values 5.6 per cent and 426 permeability respectively in the burnt sand, is

certainly interesting and difficult to explain. In the first case each per cent of clay can be credited with fifty-six units of dye adsorption value as compared with seventy-six units in the sand reclaimed from the cope and cheek of the mold. In studying the mechanical analysis of the burnt sand we find that 10.1 per cent was retained on the 100 mesh screen and finer, as compared with 5.9 per cent on the original sand—a difference of 4.2 per cent—or a value equal to the difference in the clay substances of the two sands. Is it possible that the colloids which go to make up the clay substances of a molding sand, and whose colloid content is measured by the dye adsorption test, may, due to the action of the hot iron, be either partially destroyed or fused to such an extent that they are not retained in suspension and are found associated with the fine grains in a mechanical analysis of same?

4. The general appearance obtained with this synthetic sand seems to indicate that a mechanical distribution of clay substance with grains can be accomplished, producing a molding sand equally if not more desirable and effective than a natural product containing similar elements. If this is found to be true then the difficult phase of the problem of making a synthetic sand is one of securing the proper grains and clay substance, as well as the ability to develop mechanical means of mixing and preparation which will give the physical characteristics to the sand capable of being obtained on a small scale by the mixing as indicated above.

Results Show Possibilities of Synthetic Sand

The above test and recorded result is just an example of many similar tests on sands made up from sharp sand and clay without the usual molding sand or loam.

This test has revealed, in our opinion, certain possibilities in the field of synthetic sand.

Data of Experimental Work

A large number of experimental castings were made where the method of mixing of the sand and the general procedure followed in the production was carried on on a practical scale.

Results from several of these test castings are tabulated below.

Casting No. 7.

Mold made from sand of the following mix:

Composition—Per Cent.

49 Old sand
40 Lumberton sand
8 Fire sand
3 Seacoal

The Lumberton sand was added to increase the cohesiveness and the fire sand served to open up the heap.

Analysis of the above mixture shows:

Clay substance ....13.9 per cent
Through 279 mesh sieve...... 7.1 per cent
Permeability 63
Moisture .... 7.3 per cent
Dye adsorption value 958
Cohesiveness 184

From a study of the actual venting properties of the mold itself, the following results were obtained:

	Core of Mold	*Cheek of Mold*
Top	36 per cent	26 per cent
Middle	37 per cent	29 per cent
Bottom	38 per cent	30 per cent

The sand was mixed by hand and was machine jolted. The casting produced was very poor, it being scabby, both inside and outside.

Casting No. 8.

Mold was made from regular run of packing ring sand.

Analysis of sand shows:

Clay substance ....12.4 per cent
Through 270 mesh sieve....... 3.3 per cent
Permeability 267
Moisture .... 6.8 per cent
Dye adsorption value.........628
Cohesiveness 181

This sand was mixed by the automotive type of sand mixing machine and the mold was machine jolted. A study of the

venting properties of the mold itself shows the following values:

	Core of Mold	*Cheek of Mold*
Top	49 per cent	53 per cent
Middle	56 per cent	59 per cent
Bottom	61 per cent	65 per cent

Comparing these results with those reported on casting No. 7, you will note that this mold was much more open than the one made from the Lumberton sand mixture, a value of 61 per cent reported on the core of No. 8, as compared with a value of 38 per cent obtained at the same point on No. 7. Casting No. 8 shows no evidence of scab and the machined casting had only two small sand spots. Standard machining practice calls for one-eighth inch finish all around on castings of this type.

Casting No. 12

Mold made from sand of the following mix:

Per Cent Composition of Mixture
73 Medium strong steel sand
10 Maryland sand
7 Seacoal
10 Sharp silica sand

The per cent of seacoal in this mix was carried at 7 per cent as compared to the lower figure in several other test castings because of the fact that there was no old sand to contribute its quota of seacoal.

Analysis of different sands used and the resultant molding material is recorded below:

Table 2

		Med. Strong Steel Sand	Maryland Sand	Sharp Silica Sand	Final
	Clay Substance	6.55	11.6	0.55	9.2
Retained on	6 Mesh	1.9	....	....	2.3
	12 Mesh	3.5	....	....	2.1
	20 Mesh	14.2	....	2.7	7.8
	40 Mesh	27.4	0.8	76.0	28.3
	70 Mesh	19.4	9.5	20.1	19.3
	100 Mesh	15.3	1.9	0.3	14.7
	140 Mesh	7.9	46.8	Trace	7.6
	200 Mesh	1.5	15.4	Trace	3.3
	270 Mesh	0.5	6.2	Trace	1.1
Through	270	1.5	6.7	0.2	3.6
Permeability		...	...	...	79
Moisture		...	...	...	5.8
Dye adsorption value		464	3630	...	680
Cohesiveness		...	...	...	194

Note the comparatively low permeability and moisture content, 79 and 5.8 per cent, respectively.

This sand was mulled for three minutes and mold was jolted 130 times.

Following values were obtained on the mold:

	Core of Mold	*Cheek of Mold*
Top	35 per cent	30 per cent
Middle	35 per cent	36 per cent
Bottom	39 per cent	37 per cent

Returning to the mold values obtained on casting No. 7 we note that they are of about the same magnitude as the above and the casting produced was very scabby. With this knowledge we expected casting No. 12 to be scabby, which expectation was realized on the unmachined casting. As was further anticipated the machined casting contained many sand spots on both the inside and the outside.

Casting No. 13

Mold made from sand of the following mix:

Per Cent Composition of Mixture

79 old sand
16 fire sand
3 seacoal
2 white clay

By adding the white clay and fire sand in the above proportions we expected to obtain a strong open sand; one which would allow for the venting of the gasses and at the same time be strong enough to prevent any sand washing.

Analysis of the above shows:

Clay substance.............	13.1 per cent
Through 270 mesh sieve....	4.3 per cent
Permeability	215
Moisture	5.4 per cent
Dye adsorption value.......	628
Cohesiveness	246

While it is true that the cohesiveness is much stronger than the regular sand used for similar purposes, the permeability was appreciably lower. You will notice that the moisture content at 5.4 per cent is much lower than that obtained on regular heap sand, which value ranges from 7.0 to 7.5 per cent.

The sand was mulled for three minutes and jolted 150 times. The following mold permeability values were obtained:

	Core of Mold	*Cheek of Mold*
Top	43 per cent	44 per cent
Middle	48 per cent	46 per cent
Bottom	48 per cent	44 per cent

It is interesting to note that with higher permeability of mold values as compared to casting No. 12 we have freedom from buckles and scabs.

Casting No. 17

The mold made from sand of the following mix:

Per Cent Composition of Mixture
58 old sand
35 Millville gravel
4 fire sand
3 seacoal

Sand was hand mixed and screened through a No. 3 foundry riddle.

The analysis of above shows:

Clay substance	11.6 per cent
Through 270 mesh sieve	3.5 per cent
Permeability	254
Moisture	7.9 per cent
Dye adsorption value	596
Cohesiveness	176

The sand while on the wet side had average permeability. Following values were obtained on the mold:

	Core of Mold	*Cheek of Mold*
Top	37 per cent	37 per cent
Middle	28 per cent	43 per cent
Bottom	30 per cent	30 per cent

Here again, based entirely upon the mold values, we expected to obtain a scabby or buckled casting and were not surprised when that condition was realized.

In conclusion we wish to point out the necessity of carefully

recording all phenomenon in conjunction with molding sand control or research work.

We further wish to point out the value in our opinion of mold permeability testing as a very necessary control test as well as a test to determine the relative manner in which various molding sands jolt.

Discussion—A Study of Various Sand Mixtures

H. M. LANE: I would like to ask if you did not find a rather definite relationship between your permeability test as given by the instrument you were using, and the moisture content?

R. F. HARRINGTON: Yes, we found a similar difference or the same difference when the moisture content was high or low on the instrument used in the foundry as we did on the permeability apparatus developed by the American Foundrymen's Association in testing sand in the laboratory. I am glad Mr. Lane brought up that subject. We many times opened up a sand heap by using fire sand, and we know that opening up a heap by the use of fire sand is not economy in any sense of the word, and if we make a study of these moisture curves and permeability curves, we will soon realize that if we carry that moisture about ½ per cent lower, possibly a per cent, you will have no occasion to add that fire sand and consequently carry that much more sand in your heap, so that measuring the moisture content is very important and this machine I have described does, to a material extent, indicate a changed condition of moisture.

H. W. DIETERT: For the information of those who have the standard A. F. A. permeability apparatus, I wish to say that there is a certain application of this permeability apparatus similar to the one described by Mr. Harrington in this paper. The apparatus for showing the permeability of the mold is a much more portable machine, because you can carry it around and as soon as you have it at the mold, you can take readings without carrying around a hose and electric conduit, and our readings seem to be more consistent with A. F. A. apparatus than we could obtain from any other similar apparatus. Therefore, I propose to use the A. F. A. standard permeability apparatus for finding the permeability both of the sand in the laboratory and also on the floor.

E. W. SMITH: I would like to ask Mr. Harrington in the use of these permeability tests, what have you thought of having an open mold for the escape of gases? The question might also apply in Mr. Dietert's

use of the A. F. A. tests. Mr. Harrington, have you been able, through the use of tests, to bring around the elimination of the vent wire in the foundry?

H. W. Dietert: Yes, sir, we have eliminated the vent wire. We vented when we first started on this test. When we were in our experimental stage we had too dense a sand; we did not know it as it felt open, it was on our boiler floor and our losses were higher than they should be. We resorted to the vent wire during the winter, when our whole supply of sand was in and we did not have any coarse sand available to open up our boiler sand. We had to resort to the vent wire, but by the use of this permeability apparatus, we found out that the sand was too dense.

R. F. Harrington: We never employ the vent wire, that is, while we are dealing with coarse sand and new material, any time our sand is not of the Millville gravel type of material; this is our green sand.

I think that our general practice is to carry the sand a little too open, that is, we have reduced the defective work in the shop to a point where we seldom know what it is to have buckles and scabs, but I think it has been at the sacrifice possibly of a finish on the mold, and careful attention to these details will allow us to come down closer to the sand that is nearest suited for the job and still leave sufficient leaway for the foundry. In fact, I think that it will enable us to use a sand that the foundry could not ordinarily use unless it was followed carefully, but I am frank to say that I have little hope of a foolproof sand.

Dr. Richard Moldenke: I am trying to see if we can get something out of all these investigations that will lead to the foolproof sand, because the foundrymen cannot find skill as they used to find it and if the jolting machine is not run as it should be, they still want good castings.

R. J. Doty: I am not saying anything about foolproof sand, because I do not know whether there is any such thing. I am ordinarily pretty busy during the day, but for years it has been my practice to visit the facing sand mill morning and afternoon, and to go about the foundry on the different floors testing the facing sand we use and testing the heaped sand. That took a lot of time and it did not stop the defective castings. Since these tests have been put into practice, I find that it is unnecessary to do that. Our laboratory tells us far in advance of any change which may produce defective castings. Our foremen in the molding department and in the core department are so convinced of the reliability of these tests that if we have some defective castings they do not blame it on the sand until they find it is not something else. In other words, they are engaged to show you the change and indicate the coming of trouble in sufficient time to ward it off.

Dr. R. Moldenke: What I am driving at is to get something out of all this work for the 9,500 foundries that cannot have laboratories.

R. F. Harrington: I believe that Dr. Moldenke has brought up a very important point. A gentleman spoke to me this morning and said, "Gosh, I don't know what is going to happen when they get to grading sand. We are not all so fortunate as to have technical departments and laboratories; what are we foundrymen going to do?" I think they are going to do exactly as they have done in the case of their metallurgy; it is not possible for them all to have metallurgists on the job. The producer will hand to the user a record of the section of that sand as tested by these physical tests that the American Foundrymen's Association have recommended. I believe that with the knowledge that will be given out at these various technical sessions and with the knowledge that comes from practice, the foundrymen will be able, without these technical forces, to keep out of an awful lot of trouble. What we are after is preventive medicine instead of post mortem examinations. These curves certainly anticipate trouble; you cannot get away from it. These heaps do not change overnight ordinarily. Of course, if a fellow falls asleep on the job and lets the hose run, he will get the sand pretty wet, but that is unusual and it is generally the case of the heap building up in one respect or another, and I think what Mr. Doty has pointed out is a case of preventive medicine.

R. J. Doty: May I ask the total cost of the apparatus? The figure has escaped my memory.

Chairman W. M. Saunders: It is in the neighborhood of five or six hundred dollars.

R. J. Doty: Anyone of us would spend five or six hundred dollars a year on a little better sand, a little more expensive sand, to eliminate the defectives, because we believe it would be a good investment. Now the figure mentioned indicates to you the cost of the apparatus; there has been a great deal of talk about laboratory work, and that talk has been necessary, because much of this investigation has been in laboratories; but the follow-up work in a small foundry such as Dr. Moldenke refers to which cannot afford a metallurgist; a boy can operate this apparatus after a little training. I want to go on record as stating that we save each year in new sand more than enough to pay for the apparatus and the time of the man who operates it, because we used new sand to a greater extent that we needed to use it lest we got into trouble; now we know that no trouble is developing and we use much less new sand. The 5,000 foundries spoken of can afford this because they will save enough money to pay for it. Moreover, they do not need all the equipment for control work.

Dr. R. Moldenke: Put that in plain U. S. language so they can take it home with them and do it; that is what they are after.

R. J. Doty: They can.

CHAIRMAN SAUNDERS: It is not necessary to invest $500; you do not need an expensive apparatus for determining the fineness test; all you need is the permeability, and possibly the cohesiveness test. This whole apparatus can be put into the foundry and operated by the foreman at an expense of not more than $150. I think the permeability test is the most important of all. There are quick methods of determining moisture which are being studied now by various laboratories and probably later on will be presented for your information, but do not feel afraid that you cannot start a small testing plant of your own. A small foundry need not depend on its own laboratory; there are central testing stations, gray iron laboratories where they make a chemical analysis that, no doubt, will take up this phase of the test, and the small foundry can send its samples to the central stations.

MR. GREENWOOD: I would like to ask Mr. Harrington if there has been any comparisons made between the permeability of molds set up either by a squeezer or bumper or hand molding or a sand slinger?

R. F. HARRINGTON: We have made comparisons between the molds on a jolting machine and the same mold hand rammed, and the noticeable fact is that the hand rammed mold is less uniform than the jolted mold. We have done nothing on the other two items mentioned.

W. E. MOORE: I am interested to know what experience, if any, has been had in permeability tests on dry sand molds. Your discussion has been confined to green sand, as I understand it. I would like to know what experience has been had.

R. F. HARRINGTON: We have made, in fact we are plotting, curves that show the condition of the dry sand mold over a period of several months now; we plotted from day to day. Of course that is tests on sand that is green before it is baked, because after all that is the point in which we are most interested. When the sand is baked, we make a test of the mold in exactly the same way as we would if that test were to be made in a green sand mold. The reason we attack the problem at that point is because when that mold is leaded over with a graphite wash, it is almost impervious anyway. Now, many people will say, "Well, what is the good of making these permeability tests if the mold is impervious after you put the lead on it and cast the metal after the lead is on there?" But I think we recognize that, although when you put your facing on you reduce the permeability from 50 to 5 per cent on the actual surface, you are not carrying the gases away from the metal because they are all contained in the mold and the mold is still capable to taking away those gases. If considered entirely from the standpoint of the gases contained in the mold, the fact that you put on a graphite facing and reduce the permeability of the actual surface, you do nothing to affect the result, because you are interested in taking the gases away from the mold itself.

Testing Molding Sands to Determine Their Permeability

By T. C. Adams, Ithaca, N. Y.

Those who cast metal recognize the necessity of using for their molds some material which allows the ready passage of gases through its mass. This property of the mold material has been termed permeability. Sand or a mixture of sand with some binding material is universally employed for molds. Different sands have very different properties. To keep losses of castings due to molding sand troubles at a minimum, methods of testing the properties of the sands used in the foundry, which properties include permeability, have become more and more necessary. This paper deals entirely with testing to determine permeability.

In a modern foundry permeability determinations may have two objects, viz: 1. Tests of new sands to determine adaptability to the uses of the foundry, 2. Tests for the purpose of determining the condition of the sand in use on the foundry floor. Tests for the latter purpose may be made at regular intervals so that the sand heaps may be kept in the condition best fitting them for the uses of the foundry by changing the water content of the heaps or by blending other sand into them.

To develop a satisfactory testing system some means of testing must be employed which will give a reasonably accurate comparison between different sands on the basis of the test results. For this purpose it is highly desirable that a numerical value expressing the permeability might be found which different observers working independently and using different apparatus would agree to, when testing the same sands.

In this paper an attempt has been made to review the different types of permeability apparatus that have been used, and to point out what seem to the writer to be their respective advantages and disadvantages.

Before describing these methods and the apparatus employed in connection with them a short synopsis of the physical proper-

ties of molding sands which affect the flow of gases through them will be given. Following this the development of the mathematical expression for this kind of flow and a short description of the problem involved in preparing the test specimen so that the test may meet the conditions desired will be given.

Relation of Permeability to Other Physical Properties of Sand

Permeability, the property of permitting the flow of gases or liquid through a porous body, when applied to molding sand is a physical property which varies with the size of the grain, the grading of the sand, the amount and nature and arrangement of the binding material, the amount of moisture which the sand mass contains, and the compaction. Other things equal permeability decreases as the compaction of the sand increases. The exact relation between size of sand grain and grading of the sand (percentage of various sizes of sand grains) to the permeability is hard to determine. In general, the coarser the sand the greater its permeability but this is much modified by the grading.

The relation between moisture content and permeability is very interesting. Usually the permeability of a sand increases with moisture content until some maximum value of permeability is reached after which with an addition of moisture the permeability decreases. The point of maximum permeability varies with different sands and often is at a moisture content a little lower than that at which the sand is commonly used in the foundry. Not all sands show a maximum point on their permeability curve. It is likely that the influence of moisture on minute grains of binding material is the cause of the maximum permeability point. Moisture makes these small particles flocculate or gather together into larger grains in which condition they act as larger grains. With the addition of much water the flocculated grains break down again.

If a body of sand is held in a cylinder as shown by Fig. 1. and air is forced through it from one end of the cylinder a certain relation will exist between the area of the cylinder, its length, the pressure difference between the air spaces at the two ends of

the cylinder, the permeability of the sand, and the volume of air which will pass through the sand in one minute of time. Let these quantities be represented by the following symbols:

- A area of sand cylinder
- L length of sand cylinder
- H difference of air pressure between two ends of cylinder
- K a constant depending upon the various factors of compaction, size of grain, etc., which have been mentioned above, this constant is a numerical expression of the permeability of the sand
- Q the volume of air which will pass through the sand in one minute.

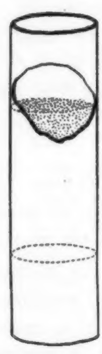


FIG. 1—CYLINDRICAL SAMPLE CONTAINER FOR PERMEABILITY TEST

For the purposes of this paper the centimeter-gram-minute system of units will be employed. Q may be at any time replaced by its equal, V divided by T, where V is the volume of air which passes through the sand in any given time T.

It has been found by careful experiments made in the sand testing laboratory at Cornell University that the rate of flow of air through sand is proportional to the pressure causing this flow. This is only approximately true but within the range of pressures met with in sand testing no appreciable error is introduced

by holding it to be exactly true. The flow of air through a sand column in addition to being proportional to the difference in pressure between the two ends is proportional to the area of the cylinder and is inversely proportional to the length. If these relations are expressed in an equation by making use of the symbols previously given and the coefficient K, then:

$$Q = \frac{V}{T} = HK\frac{A}{L} \text{ or } K = \frac{LV}{AHT}$$

If a cylinder of sand similar to the one considered above were made from a sand it was desired to test and if this cylinder were placed in an apparatus capable of passing a measured volume of air through it and fitted with some means of measuring the difference in pressure between the two ends of the column and of determining the time required for a measured volume of air to pass through the sand, the permeability of the sand in numerical units could be determined by making these measurements and substituting the values in the above equation.

The permeability thus obtained would be that which corresponds to the conditions of moisture content and compaction the sand sample happened to possess at the time tested.

It is ordinarily desired to test the permeability of a molding sand with varying moisture content but it is found most desirable to test all sands under a constant compaction. A test made upon a sample of sand which is compacted some definite and standard amount, and the moisture content of which has been determined will hereafter be called a standard test. It is easy for one to see that as the permeability of a sand changes with the moisture content and with the compaction a test of the permeability would be of no value if the values of these two quantities were not known. As there is no object in varying the compaction one standard compaction at which every sand is to be tested should be selected. To determine the moisture content at which the permeability is greatest requires that a number of tests be made upon the same sand with varying water contents.

Preparation of Sand Sample for Testing

Any sand before testing is tempered with the desired amount of moisture or is selected from the moist piles of sand on the foundry floor. In either case the moisture content is determined. This phase of testing is not within the scope of this paper. Any one desiring information concerning how this is done is referred to the instructions for standard tests issued by the American Foundrymen's Association.[1]

A convenient and satisfactory means of preparing a sand cylinder for testing purposes has been developed by the Sub-

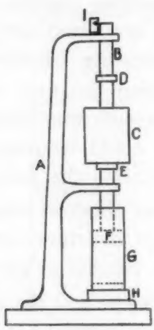


FIG. 2—APPARATUS FOR PREPARING SAND SAMPLE

Committee on Standard Tests of the American Foundrymen's Association which will be referred to hereafter as the Test Committee. The apparatus used to prepare the sand cylinder is shown in Fig. 2. This apparatus makes a sand cylinder of two inches diameter and two inches height.

The apparatus consists of a frame A which supports by means of guides the rod B which is free to move vertically. A fourteen pound weight C slides on rod B but its motion is limited to two inches by stops D and E. A brass cylinder G with a loose steel plug H in the bottom sets on the frame of the apparatus and is centered with respect to the axis of rod B. This cylinder contains the sand. The lower end of rod B carries a

[1]*Transactions*, American Foundrymen's Association, vol. 31, page 689, 1924.

steel plug F which fits loosely in cylinder G when the rod is lowered. The sum of the weights of F, B. C, D, and E is 16 pounds. A scale I is fastened to the top of the frame so that the position of the upper end of rod B can be read on it. This scale carries three marks. The middle one is set so that the top end of the rod B is even with it when the lower face of F is exactly two inches distant from the upper face of H. The other two marks are .08 inches above and below the middle one.

To prepare the sand sample for testing enough sand is selected (between 150 and 200 grams) which according to the judgment of the operator will make, after compaction, a cylinder two inches high. This is placed in cylinder G after plug H has been inserted in its bottom. The cylinder is placed in position under rod B. F, C, and B are allowed to rest upon the sand then weight C is lifted until it touches the top stop and is allowed to fall. Weight C is dropped a total of three times after which the top of rod B is observed to see whether it lies between the two outermost marks on the adjoining scale. These two outermost marks of the scale are tolerance marks. If the end of rod B does not come between the marks after ramming is completed a fresh lot of sand must be selected which will make the top end of rod B come to as near its proper position, which is level with the middle mark, as possible. If the sand cylinder is of the right height it is ready to be tested.

This method of preparing the sample insures the same compaction for each sand cylinder and nearly uniform compaction through each individual cylinder. It may appear at first that constant compaction would be obtained whether or not the completed sand cylinder was two inches long or not and that in testing, the various lengths of differing cylinders could be taken into consideration in the formula by which the permeability is computed. Contrary to this it has been found necessary to specify the length of the sand cylinder in order to obtain constant compaction and thus comparable results from various tests. To the same end it is necessary to specify the diameter of the sand cylinder.

In the description of the permeability apparatus which follow, it is evident that the sand to be tested has in all cases been

pressed into a cylinder, but conditions of compaction similar to those described above are known to have been used only in the first seven types described (Figs. 3 to 11 inclusive).

Recapitulation of Significance of Permeability Formula

The formula $K = \frac{LV}{AHT}$ forms the basis of all permeability testing work where an attempt is made to calculate the permeability to a unit basis. This is the procedure recommended by the Test Committee. As this practice has much in its favor and is being generally adopted attention will be called here to the significance of the various factors in the formula. K is the permeability of the sand which varies with the physical condition of the sand, viz: compaction, moisture content, size of sand grain, etc. The factors on the opposite side of the equation are those measured when the sand sample is tested. These factors are usually measured in centimeter-gram-minute units. If so, K is the number of cubic centimeters of air which would pass through a cubic centimeter of sand in one minute of time if the pressure difference causing the flow is one gram per square centimeter.

Description of Permeability Testing Apparatus

Starting at this point, a description and discussion of the various types of apparatus for determining the permeability of molding sands will be taken up and in doing so to both expose the theory underlying their action and to comment on the practical advantages and mode of operation of each. The first five apparatus described have been tested in the sand testing laboratory at Cornell University according to the instructions of the designers of the apparatus.

Permeability apparatus may be very naturally divided into two main groups as follows: 1, those which determine with the aid of the permeability formula, the permeability of the sand in some definite units (usually centimeter-gram-minute units), 2, those which give the permeability in some very arbitrary unit which depends upon the construction of the apparatus. All results obtained from any apparatus of the first group named are comparable with results from any other apparatus belonging to this group. Results obtained using any apparatus of the second

group are only comparable with those obtained using the same design of apparatus when each apparatus made after the given design is strictly standardized, otherwise results may not be compared except with other results obtained upon the one individual apparatus. The advantage possessed by the first group of apparatus is very apparent.

An apparatus of the first group which measures each of the values of time and pressure independently with the intention that these will be substituted in the permeability formula for the calculation of the permeability is termed a direct apparatus. Others of this group which involve calibration of the apparatus or which employ complicated relations permitting the permeability to be obtained by a measurement of one variable alone are called indirect apparatus.

I—Apparatus Giving Permeability Using American Foundrymen's Association Units

Bureau of Standards Apparatus

The first type of apparatus, named the Bureau of Standards Apparatus, was suggested first by C. P. Karr of the U. S. Bureau of Standards. It was among the first apparatus considered by the Test Committee and in its present form is the result of various modifications suggested from time to time. The Bureau of Standards apparatus is shown diagrammatically in Fig. 3. It is of the water displacement type.

The essential parts of the B. of S. apparatus are a constant level bottle A connected by a tube to a displacement bottle G (Fig. 3). The constant level bottle A is supplied with water through pipe B. The flow of water is controlled by valve C. There is also an overflow D which maintains a nearly constant water level in A. The displacement bottle G is provided with two additional openings beside the one through which the water flows into it from A. One, H, is at the top of the bottle and serves as an air outlet. The other, L, is at the bottom and serves to drain the bottle when valve M is open. Connected to L and H is a vertical tube N. This tube is a water level gage for displacement bottle G. The water stands in tube N at the same level as in the bottle because of the cross connection of its top with

the air outlet H and its bottom with L. At the top of N is a valve K which is opened to admit air to bottle G when it is being drained but is closed when the permeability of a sand is being determined.

One branch, O, of the air outlet H leads to sand cylinder I containing the compacted sand, where an air-tight connection is made by means of a rubber cork. A branch from O connects with manometer J. Manometer J consists of a glass tube about five feet long bent in the middle to form a long narrow U shaped pipe each leg of which is two and one half feet long. This tube is vertical and is half filled with water which may be colored if

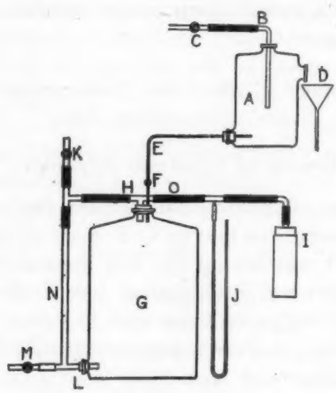


FIG. 3—KARR APPARATUS

desired. Along each leg of the manometer is a scale reading in centimeters. A stop watch completes the list of apparatus.

Bottle A is about three liters capacity. Bottle G is about four liters capacity. The distance from the water surface in bottle A (level of overflow D) to the lower end of tube E is made 22 inches or 56½ centimeters. This tube is a six millimeter tube (internal diameter) and stop cock F is a glass one and has an accurately ground 4 millimeter hole in it.

Before the apparatus is operated two marks are placed on tube N at such a spacing that the capacity of bottle G between

them is two thousand cubic centimeters. To do this water is poured into bottle G until the level of the water in it and in tube N is an inch or so above the outlet L. This elevation is then marked on tube N by a scratch on the glass or by a piece of paper glued on. Two thousand cubic centimeters of water are then poured into bottle G. The second mark is then placed at the new level of the water in tube N. Tube N must be very clean so that the level of the water in it may not be affected by erratic surface effects while the two marks are placed. During the process it is, to be sure, necessary to keep the outlet to bottle G tightly closed and to be certain no water except that poured in enters the bottle.

To operate the apparatus valves F, K, and M are opened and then valve C is opened to admit water to bottle A until a very small stream overflows from D. This need be done but once a day.

Valve F is then shut and after bottle G has drained, valves K and M are also shut. A sample of sand which has been prepared as described in the forepart of this paper is then placed at I with the rubber cork in the end of the brass cylinder making an air-tight connection with the air pipe O. The valve F is then opened wide allowing a stream of water to flow into G. The operator stands ready with the stop watch which is started at the moment the water level in tube N reaches the lower mark on that tube. The pressure indicated by manometer J is noted during the time the water is rising between the marks on tube N. At the moment the water level in tube N passes the second mark the stop watch is stopped. The time indicated by the stop watch is the time which will be designated by T. The pressure indicated by manometer J is called the pressure and is designated by H. This pressure should be determined as in all U tube manometers, viz; by taking the sum of the rise in one leg and the fall in the other leg, both in centimeters. The permeability of the sand sample is then calculated by the formula $K = \frac{501}{H\,T}$.
This formula is the same as that developed in the fore part of this paper after the proper values for L (length of sand sample), V (volume of air), and A (area of sand cylinder) have been

substituted in it and a simplification made. The area and length of the sand sample are always the same when the sand sample is prepared as has been described (Test Committee method) making possible the use of this abbreviated formula.

The principle of operation of the Bureau of Standards apparatus is that a given quantity of air is displaced from a bottle and made to flow through the sand sample at a rate and at a pressure which is determined by the permeability of the sand.

If q is a rate of flow of water in cubic centimeters per minute and is equal to $\frac{v}{t}$ where v is the volume in cubic centimeters which flows in t minutes, the formula expressing the rate of flow of water through a short tube with a valve in it such as E in Fig. 3, is $q=c\sqrt{h}$ where h is the pressure forcing the water to flow through the tube and c is some constant which remains the same for any given tube arrangement. Also $\frac{v}{t}=c\sqrt{h}$.

According to the permeability equation $K=\frac{LV}{AHT}$ the time for a given volume of air to flow through a sand cylinder and the pressure set up by the resistance of the sand at that rate of flow determine the permeability of the sand. If no sand is in cylinder I, water from bottle A will flow into bottle G at a certain rate depending upon the difference in level between the water in A which is kept constant by the overflow D and the lower end of tube E. This is equivalent to saying a definite time will elapse for two thousand cubic centimeters of water to collect in bottle G. The water is at the same time displacing two thousand cubic centimeters of air through the tube O into the atmosphere at the same rate water flows into G. There is no back pressure existing in G. The permeability in this case is infinite. If now, a cylinder of sand is placed at I instead of an empty cylinder, a back pressure will develop in G which will retard the flow of water from bottle A and consequently the rate of air flow through the sand. It will then take a greater time for two thousand cubic centimeters of air to flow than before. Similarly a sand less permeable would set up a higher pressure and

require a longer time for two thousand cubic centimeters of air to flow from bottle G. If the outlet at I were entirely stopped up (this would be equivalent to having a sand with a permeability of zero) the manometer would indicate a pressure equal to the pressure developed by a column of water of a height equal to the difference in elevation between the water level in bottle A and the lower end of tube E. Also the rate of flow would be zero or the time for two thousand cubic centimeters of water to flow into G would be infinite.

In the Bureau of Standards apparatus tube E is made a certain diameter and length and the hole in stop cock F is made a certain diameter each dimension being constant for all apparatus. Also the difference in elevation between the water surface in bottle A and the lower end of tube E is made constant for all apparatus. When no sand is in the apparatus and air is free to escape from bottle G without hindrance it has been found that water will flow into bottle G at the rate of one thousand cubic centimeters in .43 minute. This enables the calculation of c in the formula which was given in the third paragraph previously as follows:

$$c = \frac{v}{t\sqrt{h}} = \frac{1000}{.43\sqrt{56.5}} = 309$$

As has been said, when a sand sample is being tested there is a certain back pressure in the bottle G equal to H of the permeability equation. The pressure which is forcing water through tube E is decreased by this amount or is equal to h — H. Then with a sand sample in the apparatus, h should be replaced by h — H in the formula for the flow of water through the tube. Making this substitution and solving for t gives: $t = \frac{v}{c\sqrt{h - H}}$
As the rate of flow of air exactly follows the rate of flow of water (when equilibrium is established) because the latter displaces the former causing its flow, t and v correspond to T and V which may be substituted in their place. Thus:

$$T = \frac{V}{c\sqrt{h - H}}$$

This formula shows a dependence of T upon H, when one is

known the other may be calculated because for any given tube and apparatus c, H, and V are constant. How this relation will be used to simplify the operation of the apparatus will be shown later under the discussion of the modified Bureau of Standards apparatus.

It was originally thought that the permeability of a sand as expressed by the formula $K = \frac{VL}{HTA}$ would not be an exact one, varying because either H or T came into the formula at some other power than the first power and that the exponent of H or T might depend upon the size of the sand or other of its properties. Because of this belief it was held that a sand must be tested by some strictly standardized apparatus where every condition of pressure and time for a given flow of air would be the same for all sands having the same permeability. The Bureau of Standards apparatus meets these qualifications. According to the best experimental evidence the permeability of any given sand is truly expressed by the formula and does not change with changed conditions of testing. If H is increased there will be a corresponding decrease in T just enough to compensate for the increase of H. Therefore there was no need of standardization of the B. of S. apparatus and more flexibility of design could have been allowed.

The B. of S. apparatus is accurate in the testing of all sands except those having a very high premeability (a thousand or more). These sands set up such a low pressure in the manometer as to make the reading inaccurate. The use of the stop watch is objectionable for most stop watches are not reliable for continued use.

The apparatus might be materially improved by changing the design somewhat and possibly omitting the standardization of parts entirely. The stop cock F can be omitted if an outlet to G is provided with reasonable capacity and the apparatus may be made more compact if the distance between the water surface in bottle A and the lower end of tube E is made shorter.

Farther on in this paper a modified Bureau of Standards apparatus is described which makes use of these improvements but operates in a somewhat different manner.

Grubb Permeability Apparatus

A second type of permeability apparatus is that devised by A. A. Grubb of the Ohio Brass Co. This apparatus draws a measured quantity of air through the sand instead of forcing the air through it as is done by the Bureau of Standards apparatus.

In Fig. 4, A is a bottle of about four liters capacity with two necks and a tubulature at the bottom. The brass cylinder G containing the sand is corked with a two holed cork.[2] One hole of this cork connects through a tube with manometer F and the other hole connects with a vertical tube which extends through a cork in one of the necks of bottle A to near the bot-

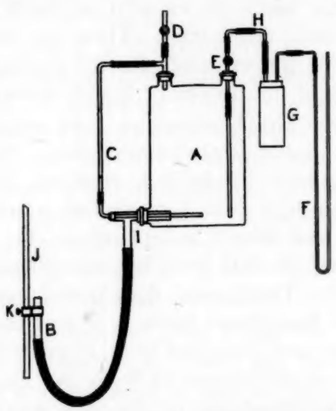


FIG. 4—GRUBB PERMEABILITY APPARATUS

tom of this bottle. Just outside of bottle A this vertical tube has a glass stop cock E. The other neck of the bottle is corked and through this a tube with valve D makes connection between the inside of the bottle and the atmosphere. A tube which is a branch from D, runs from D to the tubulature near the bottom of bottle A. This forms tube C. C is about eight millimeters in internal diameter and is connected at the bottom by means of a complicated connection shown at I, with the interior of A. A large tube which terminates at the sliding clip K also runs to the

[2]The Grubb apparatus is often constructed with the cylinder G set directly above stop cock E.

interior of A through this same complicated connection. Instead of the manner shown the tubulature, if large enough, may be fitted with a two-hole cork to allow both C and the upper end of B to pass directly through. This would avoid the complicated detail shown for this connection. Tube B should be about one-half inch internal diameter.

From I to K tube B is flexible. The elevation of the end at B can be controlled by sliding clip K up or down on the brass rod J. It is intended that the end of tube B will be placed over a drain. A stop watch forms part of the apparatus.

Tube C is a water gage for bottle A. On tube C two marks are placed between which the capacity of bottle A and tube C is two thousand cubic centimeters. These two marks are placed in a similar way to that explained for the placing of two marks on the water gage of the Bureau of Standards apparatus.

To operate the Grubb apparatus, sand cylinder G containing the sand to be tested, is placed in position. Valve E is closed and valve D is opened. Tube B is removed from clip K and employed to fill bottle A from a convenient water supply. Valve D is then closed and tube B is replaced in clip K. The water contained in A will be held there by atmospheric pressure until valve E is opened. This is next done permitting water to flow. The water which flows from bottle A is replaced by air, which flows through the sand contained in G, through the tube H, and through valve E to the bottom of bottle A; then it bubbles up through the water remaining in A. The suction of air into bottle A causes a negative pressure on top of the sand column in the brass cylinder. The amount of this pressure is indicated by manometer F. Also the amount of suction exerted by bottle A is dependent upon the rate water flows from bottle A through tube B, which is in turn dependent upon the difference in elevation of the end of tube B and the lower end of tube H in the bottle. This varies according to how the tube is slid up and down on the rod. It is thus possible to set the pressure in manometer F by adjusting the height of the outlet of B.

As soon as possible after water starts running from bottle A the pressure in manometer F is made to read some value agreed upon by all sand testers (ten centimeters of water is suggested

by Mr. Grubb). This must be done before the level of the water in A as indicated in tube C descends to the top mark on tube C. When the water level reaches this mark the stop watch is started. As the level of the water in C reaches the lower mark the stop watch is stopped. The time thus obtained is T in the permeability formula $K = \frac{501}{HT}$.

H is the pressure obtained from the manometer reading.

The particular advantage it was hoped to gain by the arrangement of the Grubb apparatus was that all sands would be tested at one given pressure for example ten centimeters of water and the permeability obtained would be the permeability of the sand corresponding to the given pressure. The permeability of a sand would then be independent of any standardization of the apparatus. The advantage claimed is offset by the fact that the permeability of a given sand does not vary with the pressure at which it is tested. It has in addition been found impossible to select a pressure which an apparatus of practical proportions can maintain for sands of a range of permeabilities ordinarily met with. If a pressure is selected to be suitable for a sand of medium permeability it will be found impossible to reach this pressure when a sand of high permeability is being tested.

The apparatus possesses great flexibility. The permeability of a sand may be obtained by taking any readable pressure on the manometer and combining it with the time reading given by the stop watch for the fall of water level in the bottle, in the permeability formula $K = \frac{501}{HT}$.

All sands are not tested at the same pressure if this is done.

The Grubb apparatus is very economical of water as it requires no continuously running stream of water. This is a decided point in its favor where the water supply is limited or there is no running water faucet available to which an apparatus may be attached.

Little has been said concerning the air tube which goes to the bottom of bottle A. The position of this tube is an important part in the design of the apparatus. If it terminated in

the air space above the water in A the drop of water level in A would lower the head on the outlet of tube B and the flow of water from A would become less and less as the water level dropped. The pressure indicated by the manometer F would thus continually change. By carrying the air tube to the bottom of A the effect of the head of water in A is removed from the total head of water which forces the flow from A. It therefore does not matter what the height of water in A may be. The flow through B remains constant and consequently the pressure indicated by the manometer remains constant also.

The bubbling air through the water in bottle A has two disadvantages. The first is that the water surface in A and the water level in tube C is disturbed making it sometimes difficult to exactly time the fall of the water level. The second disadvantage is the inaccuracy of the time measurement for the volume of flow introduced because the volume measured is partly air bubbles in the water. This error may become appreciable for sands of high permeabilities when the air column rising through the water is at least an inch in diameter. Any volumetric error introduced by air bubbling through the water may be avoided by measuring the water in a vessel after it has fallen from the end of tube B.

Mr. Grubb has made a modification in the design of some of the apparatus by fitting them with a permanent tube, not flexible, instead of the flexible rubber tube illustrated here. With this modified apparatus a scale may be used which is placed back of the manometer and takes the place of the ordinary centimeter scale. The new scale reads directly in permeabilities thus obviating the use of the stop watch and making the operation of the apparatus much quicker. The scale is prepared by calibration against sands of known permeability.

Direct, Quick Reading Apparatus

A third type of apparatus was developed in the sand testing laboratory at Cornell University. The most important point in its operation is that it keeps the rate of flow of air through the sand constant for all sands notwithstanding what the permeability

may be. Thus the permeability of a sand obtained on this apparatus is the permeability at a certain rate of flow of air through the sand. This apparatus is another one which was designed to give the permeability under certain fixed conditions. It is now established that the permeability of a sand is the same at one rate of flow as it is at any other. In using this apparatus it is not necessary to measure the time as the rate of flow or the time for a given number of cubic centimeters of air to flow remains constant.

The apparatus will be explained by reference to Fig. 5. The essential parts of the apparatus are a top bottle C containing a

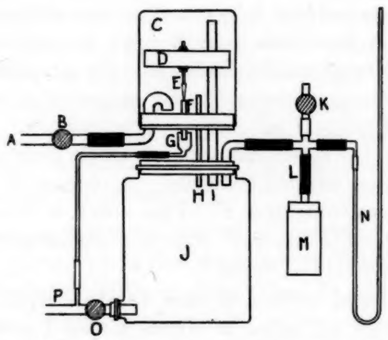


FIG. 5—CORNELL DIRECT QUICK READING APPARATUS

constant level valve and having various connections to overflow, etc., and a bottom bottle J connected to the top bottle by two tubes H and I and to the sand cylinder, the manometer, and to the drain.

Top bottle C is about ten centimeters in diameter and fifteen centimeters long. It is inverted and is closed at the bottom with a large cork. Tube A leads from the water supply to the top bottle where it is crooked to point downward. The water supply must be from a high pressure source (an ordinary faucet connected to a city water supply is usually satisfactory). It is controlled by valve B.

A tube F of brass or glass about four millimeters internal

diameter extends through the cork in the mouth of bottle C. In the top end of F is a conical plug E attached to cork D and controlled by the motion of D, which rises or falls according to the rise or fall of the water level in bottle C.

From the lower end of cone E is a spine which projects down into tube F and prevents the valve and float from being floated away from the tube and the valve failing to reseat after the water level in C falls. A tube H of glass about seven millimeters internal diameter and fifteen centimeters long runs from a point two or three centimeters above the top of the cork in bottle C down through the two corks into the top of bottle J. Another tube I about one centimeter internal diameter runs from above the water surface in bottle C to the air space in the top of bottle J. A third tube runs through the cork in the top of bottle J to the brass sand cylinder M. To this tube is connected a valve K and a manometer N. By means of a tubulature near the bottom of bottle J an outlet is provided which is controlled by valve O. This outlet should be of ample dimensions, at least one-half inch in internal diameter. A funnel G catches what water may flow from tube F. This water is then conveyed to the drain at P. It is necessary to have F discharge at atmospheric pressure just outside of bottle C.

The combined actions of tube I, which equalizes the pressure between the air space in bottles C and J and the constant level mechanism consisting of the valve parts F and E and the float D, maintain the flow of water into bottle J constant, no matter what may be the back pressure in this bottle.

The operation of the constant level valve is as follows: Water is turned into bottle C through the supply A from a high pressure source. The amount turned in is slightly in excess of the amount which will flow down tube H into bottle J when the water level stands at an elevation sufficiently high to just be able to float D and E. E is therefore raised and permits the surplus water to flow out of F and the water level in C tends to lower until it remains steady. Should there be any slight increase in the supply of water to bottle C valve E will open wider due to a raising of the float and the increment of water will flow out through F. If there is a slight decrease in water supply to bottle

C the float will lower slightly shutting off the flow from F and thus the water level in C will be maintained.

As these movements of the float are very inconsiderable compared with the distance from the lower end of H to the water surface in bottle C it may be considered that the total head or fall of the water through H remains constant.

The quantity of water which flows through tube H in a given time is dependent upon the distance the lower end of H is below the surface of the water in bottle C provided the air pressure is the same in bottles J and C. The height of the water level in bottle C is kept sensibly constant by the float and valve while the air pressure in the two bottles is kept the same by equalizing action of tube I. The flow of water into bottle J is thus constant. When the discharge valve O is closed and air valve K is also closed, water flowing into bottle J displaces air, which flows through the sand setting up a back pressure in the same manner as in the Bureau of Standards apparatus. Manometer N, Fig. 5, serves to indicate the pressure.

Before the apparatus is placed in operation the discharge from tube H is adjusted so that it will be two thousand cubic centimeters per minute. This is done either by raising the water level in bottle C, lengthening tube H, or increasing the diameter of tube H. It has been found by trial that if H has a length of 15 centimeters and an internal diameter of 7 millimeters and is placed so that its lower end is about twenty centimeters below the water level in C, it will discharge about the required amount. The final adjustment of discharge is made by raising or lowering the level of the water in bottle C through the setting of float D.

To operate the apparatus supply line A is connected to a faucet. The faucet is opened to admit just enough water to raise valve E from its seat and allow a small stream of water to run from tube F. The brass cylinder containing the sand is then placed in position as shown at M in Fig. 5. Valves O and K are closed. The pressure indicated by manometer N will then rise. After this pressure rises to its maximum, which consumes but a few seconds, and becomes steady it is read. The per-

meability of the sand is then given by the equation $K = \frac{501}{H}$. This equation is the same as the permeability equation previously given except that T has been dropped out for T remains always equal to 1 with this apparatus.

For sands of very low permeability the pressure reading is high, being for some fine sands as high as two meters of water. It is thus necessary to use in the case of fine sands a manometer filled with mercury instead of water and to change the reading of the manometer into water centimeters. A water manometer is satisfactory for all ordinary sands.

This apparatus furnishes a direct method of measuring permeabilities without the use of the stop watch. That is to say, no complicated relations, no standardization, nor lengthy calibration must be depended upon for the obtaining of the permeability.

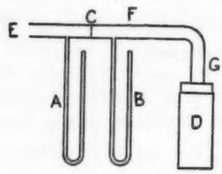


FIG. 6—SAEGER APPARATUS

Saeger Apparatus

A fourth type of apparatus for determining the permeability of molding sands is that proposed by C. M. Saeger, Jr., of the U. S. Bureau of Standards. It forms the first of what are called indirect apparatus to be described in this paper.

The essential part of the Saeger apparatus is shown in Fig. 6. It consists of two manometers A and B connected to a brass cylinder F. F is about ⅝ of an inch in diameter and about four inches long. Half way along this tube is a metal diaphragm C having a hole one millimeter in diameter through the center. A source of air supply E which is governed by a fine adjustment

valve (not shown) and a connection G to the sand cylinder complete the apparatus.

To obtain the permeability of a sand, cylinder D containing the sand is placed in position and the valve controlling the air supply is opened and adjusted until manometer A on the upstream side of the orifice indicates a pressure of ten centimeters of water. Manometer B on the downstream side of the orifice is then read. The permeability of the sand is then obtained by referring to a table previously prepared which gives the permeability of the sand corresponding to the pressure reading of manometer B.

The action of the Saeger apparatus is as follows: Air entering at E flows through the small orifice at C along through tube G and finally through the pores of the sand contained in cylinder D. In this path the air meets with two resistances, the hole in the orifice plate and the sand pores. Pressure is required to make the air flow past each of these two obstructions. The pressure required to force the air through the sand is measured by manometer B. The pressure required to force the air through both the sand and the orifice is measured by manometer A. Thus the pressure required to force the air through the orifice C is equal to the pressure indicated by manometer A less the pressure indicated by manometer B. The greater the rate of flow of air the greater the two pressures required to force the flow of air past the orifice and through the sand. This is assuming the same sand is kept in cylinder D.

With this apparatus in order to permit the making of a table which will give permeabilities without considerable calculation it is necessary to keep the pressure indicated by manometer A constant.

Consider that the sand in cylinder D is replaced by one of slightly lower permeability. It will then require more pressure to force the same quantity of air through the orifice and the new sand. If this quantity of air flows, manometer A and also manometer B indicate a higher pressure than before. This is because the pressure required to force the air through the orifice is the same as it was before and therefore the difference between the pressure readings of manometers A and B must be the same, and

since A has increased, B must increase to keep the difference constant. As mentioned before it is desirable to keep the reading of manometer A constant for any sand. To do this the rate of flow of air through the apparatus must be reduced. Both the pressure readings of A and B fall because of this reduction of flow. When the reading of manometer A reaches its original value the flow of air will be less than the original value and thus the difference in the pressure readings of the manometers will be less than originally. The pressure indicated by manometer B is then higher then it was originally. It is seen that by keeping manometer A constant there will be a certain pressure indicated by manometer B for each sand of differing permeability. The equations giving the relation between the permeability of the sand, the manometer readings, and the flow of air through the orifice and sand are developed as follows:

Let K be the permeability of the sand.

P be the pressure indication of the upstream manometer.

H be the pressure indication of the downstream manometer. This is also the pressure on the sand.

L, A, T, and V have the same significance which has been given them before in this paper. The permeability of the sand is $K = \frac{V L}{H T A}$.

The flow of air through the orifice of the Saeger apparatus is expressed by the relation $\frac{V}{T} = C_1 \sqrt{P\text{-}H}$. This equation follows from the law of flow of air through an orifice under small pressure difference which states that the flow is proportional to the difference in pressure on the two sides of the orifice to the one half power. C_1 is a constant called the constant of the orifice. The numerical value of this constant is obtained by passing a given quantity of air through the orifice at a uniform rate and measuring the time in minutes and the pressure required for forcing it through, in centimeters of water. With these values known, C_1 may be computed from the above equation in which P-H is the pressure required to force the air to flow through the

orifice. The process of finding C_1 is termed rating the orifice. This must be done for each orifice.

Solving the formula for flow of air through the orifice gives for T the value of $\frac{V}{C_1\sqrt{P\text{-}H}}$. Substituting this value for T in the equation for permeability of the sand gives:

$$K = \frac{LC_1}{A}\sqrt{\frac{P\text{-}H}{H^2}}$$

If the orifice is of such a size that 1,780 cubic centimeters of air pass through it in one minute when P-H equals ten centimeters of water and it is assumed that a sand sample two inches in diameter and two inches high will be used in the test and also that when testing P will always be made equal to ten centimeters of water, the above equation reduces to:

$$K = 140.8\sqrt{\frac{10\text{-}H}{H^2}}$$

The size of orifice used in this illustration is found to be a very satisfactory size for testing the medium range of sands. It is about one millimeter in diameter.

The general formula with the proper constants inserted may be used to prepare a table for giving the permeability values corresponding to H values for any apparatus. Such a table will depend upon the value of P adopted remaining constant for all tests. This explains the stipulation made earlier in the description of the action of the Saeger apparatus.

The Saeger apparatus has been found upon trial to be very satisfactory for the testing of sands within the range of permeabilities of from 10 to 500 when one size orifice of about a millimeter in diameter is used and when the upstream manometer is held at ten centimeters water pressure. The effect of making the orifice larger would be to increase the range of the apparatus for sands having a higher permeability but would shorten the range in the opposite direction. A diminution of the size of the orifice would act in the opposite way. By making the manometers longer and holding the pressure in the upstream manometer at a higher value the practical range of the instrument is ex-

tended in both directions. If the pressure in the upstream manometer is maintained at forty centimeters of water and the orifice is constructed to have a constant of about three hundred (C_1 equals 300) which would give an orifice about eight-tenths of a millimeter in diameter, the instrument will be found satisfactory for sands within the range of permeability from 2 to 1,000, which range is sufficient for practically all purposes.

Another suggested change in the apparatus would be to use mercury in both manometers. This would require higher pressure for the air supply but would greatly increase the accuracy of the apparatus for low permeability sands. For sands of high permeabilities the mercury manometer on the down stream side would not be satisfactory and an auxiliary water manometer would be necessary. The apparatus would be much improved by connecting one leg of manometer B to the downstream side of the orifice as at present and the other leg to the upstream side of the orifice. This would eliminate the error which might be introduced by small departures of pressure on the upstream side of the orifice from what they were intended to be. With such an arrangement of the manometers a formula somewhat different from the one just derived would have to be used.

The sources of air supply which have been suggested for this apparatus are: 1. high pressure air line such as one found in a foundry, 2. cupola blast line, 3. any low pressure air line, 4. water displacement apparatus, 5. small pressure tank pumped up by hand such as a gasoline blow torch tank, 6. aspirator apparatus for a water faucet, and 7. small constant pressure gasometer.

The gasometer as used with the orifice will be discussed under a description of another apparatus using this combination. The small pressure tank and cupola blast have not been tried. The low-pressure air line was found to be satisfactory. The water-air displacement apparatus was found to work well on all but small flows (tight sands) where it was not satisfactory. The aspirator was found to not be satisfactory as its action is too unsteady. To use the high pressure air line the valve controlling the air supply must be handled very carefully or the water in the manometers will be blown out. This last has been

worked very satisfactorily with an automatic valve which maintained constant the pressure on the upstream manometer at the value desired. An exceedingly constant air pressure on the upstream side of the orifice is very necessary with the Saeger apparatus. This is hard to obtain from any air supply line.

Modified Bureau of Standards Apparatus

Experience with the original Bureau of Standards permeability apparatus made evident certain undesirable features which might be corrected. The modifications introduced to transform the Bureau of Standards apparatus into the Modified Bureau of Standards apparatus make the apparatus less bulky, quicker in operation, and simpler.

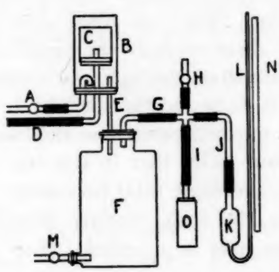


FIG. 7—MODIFIED BUREAU OF STANDARD APPARATUS

Fig. 7 is a diagram of the apparatus as constructed. It consists of an upper bottle or jar B, a lower displacement bottle F, together with the manometer K, air valve H, and the sand cylinder O. The top bottle B is supplied with water through a tube in which is inserted controlling valve A. Within bottle B is an overflow C built of a short piece of two inch glass tubing placed vertically and with a cork in the bottom through which a half inch tube runs down and through the cork in bottle B to the drain at D. If sufficient water is supplied to B, the water level within it will rise until it reaches the lip of C, when water will run out through tube D to waste.

From bottle B a tube E about six millimeters internal

diameter and thirty-five centimeters long runs into bottle F. The bottom of tube E is forty centimeters below the level of the overflow C. Bottle F is drained through a tubulature near the bottom. The drain tube is controlled by valve M. Tube E and another tube G having two branches I and J extend through the cork in the top of bottle F. Valve H is connected to tube G. Branch tube I serves to lead air from the bottle to the sand cylinder O. This tube should be one half inch internal diameter. Tube J leads from tube G to the manometer. An ordinary type of manometer could be used with this apparatus but it is advantageous to use the one shown in Fig. 7. This consists of a large vertical cylindrical tube K about three or four centimeters in diameter forming one leg of the manometer and a small tube L about five millimeters in diameter (both internal diameters) forming the other leg. They are filled with water so the level of the water stands about midway the height of tube K. When air pressure is transmitted through the connecting tube J the water level in tube K falls and that in tube L rises. The rise in tube L, however, is much greater than the lowering in K. Also the rise in L is about twice that in one leg of an ordinary U tube manometer for the same total pressure. This allows about twice the range for the scale reading directly in permeability with which this apparatus is provided. How this scale is made will be given hereafter.

To determine the permeability of a sand using this apparatus water is admitted to bottle B until it flows over the lip of overflow C. The cylinder containing the sand to be tested is placed in position at O with the cork making connection with it and tube I fitted tightly. Valves H and M are then shut. After the water level in leg L of the manometer has risen to a height where it remains steady its position on the scale is noted. The scale reading at this position is the permeability of the sand.

The operation of this apparatus is the same as the unmodified Bureau of Standards apparatus. Drain M is made of sufficient capacity to drain bottle F as well as to allow the discharge from E to pass through it at the same time. Because of this no valve is required in E.

To determine the relation between the rise of the water in

leg L of the manometer and the permeability of the sand, equation $t = \frac{v}{c\sqrt{h\text{-}H}}$ developed in connection with the unmodified Bureau of Standards apparatus and the permeability equation $K = \frac{VL}{HAT}$ will be used. c is the coefficient of tube E Fig. 7 corresponding to tube E Fig 3. v is the volume of water which flows through tube E in time t. h is the difference in elevation between the lower end of tube E and the water surface in the bottle above, and H is the pressure in the sand cylinder forcing the air through the sand and also the air pressure in the lower bottle F. The symbols in the permeability equation have the same significance they have been given before. v corresponds to V and t corresponds to T as the water displaces air cubic centimeter for cubic centimeter. T and V may, therefore, replace t and v in equation $t = \frac{v}{c\sqrt{h\text{-}H}}$ which is then $T = \frac{v}{c\sqrt{h\text{-}H}}$.

If this value for T be substituted in the permeability equation, this last becomes, after reduction: $K = \frac{Lc}{A}\sqrt{\frac{h\text{-}H}{H^2}}$ which is an equation of the same form as that derived for the Saeger apparatus. This equation gives the permeability of of the sand in terms of the dimensions of the sand sample, the co-efficient of tube E, the difference in elevation between the water surface in the bottle above E and the bottom end of E, and the pressure H on the sand. This equation is to be modified by substituting for H the equivalent of H in terms of the rise of water in leg L of the manometer. For the purpose of developing this relation let F_1 be the cross-section area of leg K of the manometer, F_2 be the cross-section area of leg L of the manometer, R_1 be the lowering in water level in leg K, and R_2 be the rise in water level in leg L. $R_1 + R_2 = H$ and $\frac{F_1}{F_2} = \frac{R_2}{R_1}$

The first of these equations may be altered to $R_2\left(\frac{R_1 + R_2}{R_2}\right) = H$

in which the term inside the brackets can be shown to be a constant, which will be called C_2, equal to $1 + \frac{F_2}{F_1}$. H then equals R_2C_2, and this value may be substituted for H in the equation for K, which has been developed for the modified Bureau of Standards apparatus. The equation for K becomes:

$$K = \frac{Lc}{A}\sqrt{\frac{h - C_2R_2}{(C_2R_2)^2}}$$

To determine the numerical value of C_2 for any manometer, scales are attached to legs K and L and a pressure applied to K. R_1 and R_2 are then read on the scales; then, by substitution of these numerical values in the equation $C_2 = \frac{R_1 + R_2}{R_3}$ the value of C_2 can be computed.

To determine the numerical value of c for any tube E, bottle F is removed and the discharge from tube E received in a vessel of known volume. The time required to fill the vessel is obtained with a stop watch and h is measured very accurately with a scale. These values are then substituted in equation $t = \frac{v}{c\sqrt{h\text{-}H}}$ with H equal to zero and the value of c computed.

The numerical values of these two constants, together with the numerical values for L, A, and h may be substituted in the equation for K, as last derived, to form what may be called a working equation. The working equation may be used to calculate the permeability of a sand from a reading of the rise of water in column L of the manometer, or it may be used to prepare a scale which can be attached to the instrument to read permeabilities directly. It is intended, with this apparatus, that the scale will be prepared and placed alongside of leg L of the manometer. The zero of this scale must at all times be level with the level of the water in leg L of the manometer, when there is no pressure on the manometer.

The modified Bureau of Standards apparatus requires a continuous water supply, though not a high pressure source. It can be built of such size as to be easily transportable. If de-

sired the modified Bureau of Standards apparatus can be used in the same manner as the unmodified Bureau of Standards apparatus.

American Foundrymen's Association Apparatus.

A diagramatic sketch of an improved apparatus recommended by the Test Committee as a substitute for the original Bureau of Standards apparatus is shown by Fig. 8. The committee has suggested certain modifications to make it better adapted to use in a foundry. These modifications will be described after the operation of the apparatus as a standard apparatus is described.

For standard tests a fair degree of accuracy is required. This accuracy must be maintained over the complete range of sands used in foundry work. In addition, no excessive pressures should be employed. It is also desirable to use in standard tests a direct method in which all quantities are measured and in which no complicated mathematics are introduced. The gasometer principal of operation adopted by the committee and incorporated in the standard apparatus meets all of these requirements very well.

Referring to Fig. 8, it will be seen that the apparatus consists essentially of a small, carefully made gasometer, connected by a large tube and a three-way valve to a sand cylinder arranged below the gasometer. A manometer is provided to read the pressure existing at the top of the sand contained in the sand cylinder.

The gasometer is built of two sheet metal tanks, A and I. A is five and one-half inches in diameter and twelve inches high. I is six and one-half inches in diameter and twelve inches high. Tank I, called simply the tank, has a tight bottom, through which the tube E passes and extends to the top of the tank. To the lower end of tube E is soldered the three-way valve J. The tank is filled to within about four inches of the top with water.

Tank A, called the bell, is closed airtight at the top and is open at the bottom. Soldered inside of the bell on its axis is

a tube, D, which has an easy sliding fit over tube E. Both tubes E and D should be rolled or turned brass and should slide one inside the other with a total clearance of not more than one thirty-secondth of an inch. These two tubes act as guides for the bell to slide up and down on and also conduct air from the interior of the bell to the sand cylinder below. To admit air to the interior of the tubes a generous area of holes is bored at the top of tube D, as shown at F. Tube E should be about one inch internal diameter. A handle, B, is provided on top of the bell. Weight C is provided, which may be centered on top of

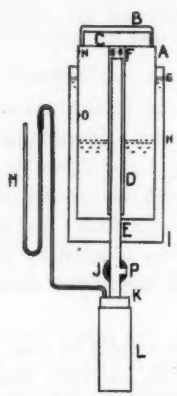


FIG. 8—A. F. A. STANDARD APPARATUS

the bell. How heavy this weight should be made, will be shown later.

Three-way valve J is situated two or three inches below the gasometer. To the lower end of valve J is attached a short piece of tubing about an inch in diameter. Over this is slipped a No. 11 rubber stopper, K. This stopper shuts tightly the upper end of the sand cylinder L, containing the rammed sand sample which is to be tested. Manometer, M, makes connection through stopper, K, to the inside of the sand cylinder by means of a copper tube. By means of the three-way valve J, the inte-

rior of the bell of the gasometer may be put in connection with the atmosphere through port P, may be put in conection with sand cylinder L, or may be shut off from both. A stop watch completes the apparatus necessary for making standard tests.

The operation of the gasometer is as follows: When the bell is placed in the inverted position in the partially filled tank it entraps air and if there is no outlet provided for the air the bell only sinks until the water on the outside of its rises to a sufficient height to produce the proper buoyancy. The condition for buoyancy is that the water displaced is equal in weight to the body which displaces it. For the gasometer, the volume of water displaced is equal to the difference in height of the water inside and outside of the bell multiplied by the area of the bell. If this height is in centimeters and the area in square centimeters, the volume obtained is also the weight of the water in grams and this according to the principles of buoyancy is the total weight of the bell and whatever weight that may be attached to it (provided the weight is not immersed in the water). It is possible to write the following equation to express mathematically the above: $X a = w$, where X is the difference in water level between the inside and outside of the bell in centimeters, a is the area of the bell in square centimeters, and w is the weight of the bell and attached load in grams.

The difference in water level X is also the pressure of the air inside the bell, and, therefore, H may be substituted for X, making $H = \frac{w}{a}$. The pressure of the air in the interior of the bell is thus directly proportional to the weight of the bell and is inversely proportional to its area. To increase the pressure, it is only necessary to add more weight to the already constructed bell. (This development neglects the loss of weight of the edge of the bell, which is submerged by water rising on both sides for a short distance.)

As the pressure of the flowing air on top of the sand is dependent upon the weight of the bell it remains constant, and is set by the construction of the apparatus. As constructed for the Test Committee the pressure is made ten grams per square centimeter, when weight C is placed on top of the bell,

or about five grams per square centimeter when this weight is not on the bell. There may be some loss in pressure due to friction of air passing through the tube and valve when the flow is rapid, as when testing coarse sands. This friction loss would introduce an error were it not possible to read the pressure on the sand by means of the manometer provided with the apparatus.

On the side of the bell, two marks are placed, which indicate that the volume between them is two thousand cubic centimeters. They are placed on a small strip of brass soldered on the opposite side of the bell from the seam. The location for the bottom mark is found by raising the bell with the weight on it until it is clear of the water in the tank, then shutting off the valve and allowing the bell to settle back. Additional water is then added to the tank until the level is one inch from the top. The lower mark is then located on the bell about one-half inch above the top edge of the tank. The top mark is placed by measurement, based on a calculation which gives the length necessary to include a volume of two thousand cubic centimeters. This distance is given by the formula $L = \frac{8000}{\pi D^2}$, where L is the length sought and D is the diameter of the outside of the bell, both in centimeters, and π is equal to 3.1416.

Weight C is made detachable, giving two pressures, because the time which must be obtained for the descent of the bell would be too short in the case of the ten centimeter pressure when testing coarse sands to obtain accurate results. The lower pressure is employed when testing coarse sands and a greater time obtained.

To test a fine sand with the apparatus the sand is rammed in the sand cylinder and the cylinder placed at L as shown in Fig. 8. Valve J is turned to the venting position and the bell raised clear of the water in the tank. Valve J is then shut off and the bell allowed to settle into the tank. The weight should be on top of the bell. Valve J is turned to connect the bell with the sand cylinder and the bell starts slowly to descend. The stop watch is started as the lower mark on the bell passes the

top edge of the tank. As the top mark passes this same point the stop watch is stopped and the time is noted. The pressure indicated by the manometer is read during the descent of the bell, after which the permeability of the sand is given by the formula $K = \frac{501}{H\,T}$, where K is the permeability, T is the time in minutes for the descent of the bell, and H is the pressure in centimeters of water indicated by the manometer. To test coarse sand the same procedure is followed, except that the weight is removed from the top of the bell. In case of testing a very coarse sand, the time is likely to be so short that the pressure cannot be read by one operator, who must, in addition, observe the time. In this case there is no objection to raising the bell and allowing it to descend a second time in order to observe the pressure.

The operation for determining the permeability of a molding sand which has just been described will give the permeability of a sand with a very satisfactory degree of accuracy no matter what the permeability may be. The operation is, however, one requiring considerable time and, in addition, requires a stop watch. To make determinations of permeability speedily, an attachment has been recommended by the Test Committee, which will now be described.

This attachment is shown in Fig. 9, which is a detailed cross section of the attachment, and the lower end of the standard apparatus. At the top will be seen the lower end of tube H, which is tube E in Fig. 8. This tube conducts air down to the sand from the gasometer above. Below tube H is the valve F and below this a short attachment, D, screwed into valve F, which serves to attach cork E. Tube L leads to the manometer. N is the sand cylinder containing the sand O. All these pieces belong to the standard apparatus without the attachment. The attachment consists of threaded tube D on the inside at the lower end and supplying two orifices in brass holders, one of which is shown screwed in tube D at A in Fig. 9. These orifice holders carry gold-lined orifices. One has an orifice about one-half millimeter in diameter, which passes two thousand cubic centimeters of air in 4½ minutes under a pressure of ten centi-

meters of water. The other is about one and one-half millimeters in diameter and passes two thousand cubic centimeters of air in 30 seconds.

If the pressure of the air above one of these orifices is kept constant there will be for each orifice a certain pressure indicated by the manometer for every permeability value of the sand tested in the cylinder below the orifice.

The Test Committee which developed this apparatus has worked out the relation between the pressure indicated by the manometer and the permeability of the sand for the two orifices

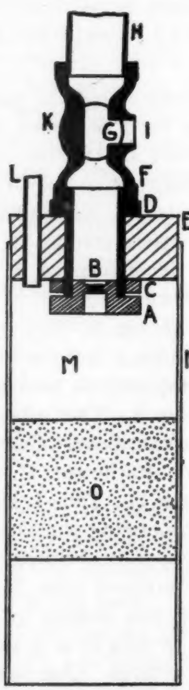


FIG. 9—DETAILS SHOWING ORIFICE ATTACHMENT FOR A. F. A. APPARATUS

selected. This relation is published* by them in tabular form.

The gasometer of the apparatus furnishes air at a pressure of ten centimeters of water to the upstream side of the orifice. In order to give a sufficient accuracy over the range of permeabilities found in ordinary molding sand practice two orifices must be provided with the apparatus. The American Foundrymen's Association apparatus operated with the orifices employs the principle of the Saeger apparatus and the relation between permeability and pressure on the sand is worked out exactly as for that apparatus.

To obtain the permeability of a sand by the modified method (employing the orifice) the valve is turned to vent and the bell raised. The valve is then turned off and the bell allowed to settle. The weight provided with the apparatus must be in place on top of the bell. If a coarse sand is to be tested the large orifice is screwed in place. If a fine sand is to tested the small orifice is used instead of the large one. The sand is then placed in position and the valve turned to the "on" position. The pressure indicated by the manometer is then read, after which the permeability of the sand is obtained by reference to the table furnished with the apparatus, which gives the relation between pressure and permeability for each orifice.

The orifices for the apparatus are drilled to the size given and then tested by means of the gasometer and stop watch. If they do not give the required flow it is necessary to ream them out or batter them down according to whether the resulting time for a flow of two thousand cubic centimeters of air is greater or less than that desired. The gold lining is not a necessity. Its purpose is to reduce the likelihood of the orifice changing after having once been calibrated. The orifices furnished with apparatus are already calibrated.

Makeshift Apparatus.

Even though a standard apparatus specified for making a standard permeability test may not be available, it is yet possible to make a very satisfactory test of the permeability of a sand,

**Tentatively Adopted Methods of Test and Resume of Activities of The Joint Committee on Molding Sand Tests* American Foundrymen's Association pamphlet, June 1, 1924, p. 53.

using only what apparatus can be quickly made from inexpensive materials which are at hand nearly everywhere. A suggestive apparatus is now to be described. This apparatus will be referred to as the "makeshift apparatus." To complete the test of a sand, it is necessary to provide a ramming device, a sand cylinder, and a permeability testing apparatus.

The sand cylinder is shown at D in Fig. 10 and at H in Fig. 11. It may be made from a piece of two-inch brass tubing or a

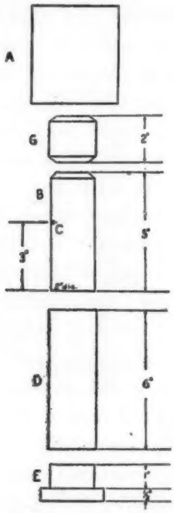


FIG. 10—SPECIAL PERMEABILITY APPARATUS RAMMING DEVICE

piece of two-inch iron pipe. It should be cut exactly six inches long. The burr on the inside of the tube should be removed after cutting.

The ramming device is shown by Fig. 10. It consists of a cylindrical iron weight, A, of fourteen pounds, a cylindrical iron or hardwood rammer, B, which has three marks placed at C which are one-sixteenth of an inch apart, the middle one of which is just three inches from the lower end of B, a block, G,

of wood; D, which is the sand cylinder described in the previous paragraph, and E, a block which should best be turned from a single piece of iron.

The permeability testing apparatus is shown by Fig. 11. It consists of a bottle, B, fitted with a large cork at the top. A four-quart fruit bottle will do. On the side are two marks, placed as follows: The bottle is set on a level table and filled about three inches deep with water. A mark is then placed at the level of the water surface. Next one hundred and twenty cubic inches of water are poured into the bottle. One hundred and twenty cubic inches of water are equivalent to two thou-

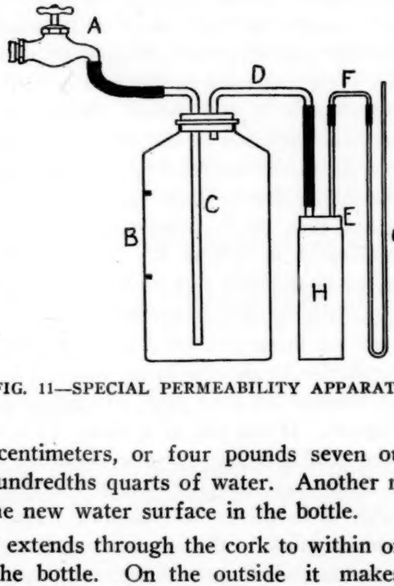


FIG. 11—SPECIAL PERMEABILITY APPARATUS

sand cubic centimeters, or four pounds seven ounces, or two and seven hundredths quarts of water. Another mark is placed level with the new water surface in the bottle.

Tube C extends through the cork to within one inch of the bottom of the bottle. On the outside it makes connections through a hose with a faucet. The tube should be one-half inch in diameter. Tube D starts just within the top of the bottle, runs through the cork and through cork E in the sand cylinder. This tube should be a one-half inch tube also and not over two feet long.

Cork E is a No. 11 rubber cork which will fit in the end of sand cylinder H. Through cork E also extends a tube, F, which runs to the manometer, G. Manometer G is made from a piece of glass tubing about two feet long and three-eighths of an inch internal diameter by heating it to redness in the middle with a gas flame or blow torch and bending it back upon itself. This tube is fastened to a vertical board. A scale divided in inches is fastened alongside of the glass tubes to enable the pressure to be read in inches of water.

To use the apparatus, the amount of sand required to make the test (selected by guess) is placed in the cylinder, which has been previously set on a stable base with plug E, Fig. 10, in its bottom. The proper amount of sand necessary to make the sand sample will usually be that which will, when loose and damp, about fill the sand cylinder Plug B is then placed on top of the sand. Weight A must be dropped upon top of plug B three times from a height of two inches. If the one conducting the test does not feel confident in his ability to hold the weight two inches above the top of the block and drop it squarely upon the top of B he may place G upon top of B, then weight A upon top of G, and then hit G a smart blow with a small iron rod which will allow A to fall on B. The distance A falls is just two inches, as G is made two inches long. The operator must be ready to catch A after it has hit B.

If at the end of three hits the top mark at C is not below the top of cylinder D and the lower mark is below the top of D, the right amount of sand was selected and the sample is ready to be tested. If the top of cylinder D is not between the two marks the sand first used must be discarded and a different amount of fresh sand selected, which the one conducting the test will judge to be the correct amount. The first trial if unsuccessful forms a guide to the second trial, so it is not likely that more than two trials will have to be made.

To determine the permeability of the sand in the cylinder, it is placed in position as shown at H in Fig. 11. Tap A is opened until a rate of flow which causes the water in the manometer to stand from one inch to a foot higher in one leg than the other enters bottle B. Then as the water rises in the

bottle the time is taken by means of a watch for the level to rise from one mark on the bottle to the other one. The difference in level of the water in the two legs of the manometer is measured to the nearest tenth of an inch, while the water in bottle B is rising. For coarse sand it will be found difficult to make this pressure greater than an inch or two, while for fine sands a very small stream admitted through the faucet A will cause a large difference in level in the manometer. It is not necessary to set this difference in level at any given value, but it should be measured accurately at the same time the interval of time is being determined. The water surface in the manometer tube will form itself into a cup-shaped surface, concave upward. This is called the meniscus, the reading should be taken to the lowest point on the meniscus.

The time required for the water in bottle B to rise from the lower mark to the upper one can be obtained by making use of the second hand of a watch. A stop watch would be convenient, but it is not necessary. The time, if determined in seconds, and the difference of water level in the two legs of the manometer in inches may be substituted in the formula: $K = \frac{11700}{H\,T}$ to give the permeability of the sand in centimeter-gram-minute units. K is the permeability of the sand, H the difference in water level in inches on the manometer, and T the time in seconds.

A test conducted according to the method just described gives strictly standard results.

II. Apparatus Giving Permeability in Other Units Than the American Foundrymen's Association Units.

The apparatus which have been described to this point have all been developed in the United States and when operated in the manner intended by the originator, give permeability in centimeter-gram-minute units. Any sample of sand will, barring incorrect manipulation of the apparatus, give the same value of permeability on any one of the previously described apparatus.

The apparatus which will be described from this point

on are intended to give a value for the permeability of the sand in purely arbitrary units. The units differ with each type of apparatus and with each individual apparatus if care is not exercised to build all the members of one type exactly as every other. They belong to the second group of apparatus as explained earlier in the paper. Values of permeability obtained for one sample of sand from two of these apparatus of different type do not bear a simple relation to one another nor to the permeability as it would be determined with one of the previously described apparatus.

The advantage of not attempting to use a particular unit is that both the necessity of making a calculation or reduction of the data, or of employing a calibrated apparatus is avoided.

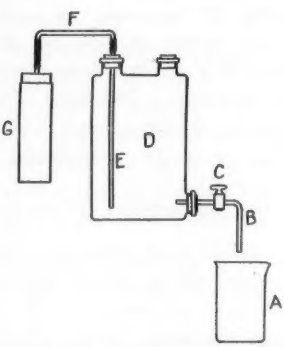


FIG. 12—GERMAN ASPIRATOR APPARATUS

A German Aspirator Apparatus.

A permeability apparatus, which has been described by C. Irresberger[3], is shown in Fig. 12. The sand sample in a cylinder, G, Fig. 12, is connected by tube F to a glass tube, E, whose lower end is carried below the water contained in flask D, and to near the bottom of the flask. An outlet tube, B, controlled by valve C allows water to flow from flask D to a receiver A. The top of flask D is airtight, therefore any water

[3] Die Formstoffe von Eisen—und Stahlgiesserei, Julius Springer, Berlin, 1920.

which flows out of it is replaced by air drawn through the sample G and entering the bottle through tube E. The lower end of tube B is exactly five centimeters below the lower end of tube E.

With the sand sample in position and the flask D filled with water the permeability of the sand is determined by opening valve C and ascertaining the number of grams of water which will flow out of tube B in one minute. Valve C is opened at the beginning of the minute and closed at the end. The quantity of water is determined from the difference in weight of receiver A and contents before and after the test. The number of grams of water is taken as the permeability of the sand.

For different individual apparatus to agree the parts B

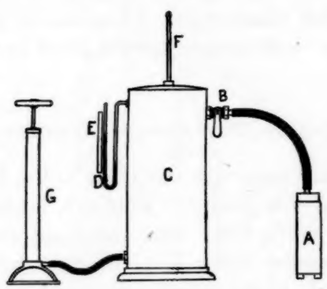


FIG. 13—GERMAN AIR TANK APPARATUS

and C must be carefully standardized and the distance intended to be five centimeters must be set with exactness. Also the parts F and E must be reasonably near the same size for all apparatus.

German Compressed Air Tank Apparatus.

The permeability apparatus illustrated by Fig. 13 is also described by C. Irresberger in the same book. It consists of a tank, C, fitted with a thermometer, F, and a manometer, D, having a scale, E. The tank is inflated by means of a hand pump, G. The sand sample in tube A is attached to a tube leading from the tank. In this tube is inserted valve B.

To determine the permeability of a sand sample the prop-

erly prepared sample is placed in position at A, valve B is closed and tank C pumped up to a pressure near the maximum which may be registered by the manometer, D. The air is allowed to come to a constant temperature, which is determined by observing the thermometer. Then valve B is opened and the time required for the pressure in tank C to drop between two limits previously agreed upon and marked upon manometer scale E is observed by means of a stop watch. The more impermeable the sand the longer will be the time required, the time thus sets the permeability of the sand.

The capacity of tank C must be the same for all apparatus, and the two pressure points, between which the timing is done, must be the same in all cases for all apparatus of this type to give comparable test results. Manometer D is a mercury manometer, so that considerable difference of pressure may be read and the time made greater than if small pressure difference were selected.

English Displacement Apparatus.

A permeability apparatus described in the June, 1913, issue of the Foundry Trade Journal (English), is shown by Fig. 14. A is a tabulated bottle filled with water and connected by tube B to a second similar bottle C. The top opening of bottle C connects by tube D to the cylinder E, which holds the sand test sample. On the side of bottle C are two marks, F and G, between which the capacity of the bottle is one liter.

The diagram given by the Foundry Trade Journal must be merely to suggest the principle of the method for the apparatus in order to be operated with any degree of facility would require the addition of some means of emptying bottle C, filling bottle A, and a valve to close either the air tube D or the water tube B during the filling of bottle A to prevent water running into bottle C. Liberty is taken to add the necessary parts which are shown by dotted lines in Fig. 14. H is a tube supplying bottle A with water and controlled by valve I. On the side of bottle A a mark, J, is placed, which is just one hundred and twenty centimeters above the lower of the two marks on bottle C. L is an outlet with a valve for draining bottle C. K is a

valve in tube D, placed there to permit the filling of bottle A without water running into bottle C.

The operation of the apparatus, with these additions, is as follows: The sand sample in tube E is placed in position, valves L and K are closed, and water is allowed to flow into A by opening valve I. Some water will flow into C, compressing the air there. Bottle A is filled to mark J, while bottle C is allowed to fill to mark G by letting out air carefully through valve K. Valves I and K are then closed and the apparatus is ready to

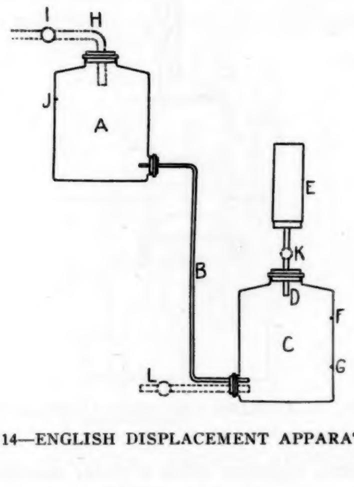


FIG. 14—ENGLISH DISPLACEMENT APPARATUS

test. Valve K is opened and a stop watch is started at this same instant. As the water rising in bottle C passes mark F the stop watch is stopped. The lapse of time indicated by the stop watch represents the permeability of the sand.

For every apparatus of this type to give comparable results a strict standardization of tube B is required and the distance, one hundred and twenty centimeters, must be set accurately.

English Gasometer Apparatus.

A second apparatus appearing in the June, 1913, issue of the Foundry Trade Journal is shown by Fig. 15. This apparatus employs the gasometer principle and thus resembles in action the American Foundrymen's Association apparatus. Referring to Fig. 15, B is a large cylindrical metal tank, filled to near the top with water. A bell, A, formed from a cylinder of metal, open at the bottom and closed at the top, floats upright in the tank. Weight C at the bottom of the bell keeps it upright. At the top of the bell is placed cylinder E, containing the sand

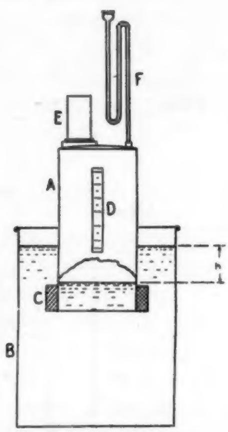


FIG. 15—ENGLISH GASOMETER APPARATUS

sample under test, together with a water manometer, F, which indicates the air pressure within the bell. On the side of bell A is a vertical scale D. The capacity of the bell is about three thousand cubic centimeters and the scale on the side indicates the displacement in cubic centimeters.

To test the permeability of the sand, the prepared sample is placed in position at E, while the bell is not in the tank. The bell is then placed in the tank and allowed to float there. It will slowly descend, due to the loss of air, which is forced out

through the sand sample. The time required for it to sink between two marks of the scale indicating a certain agreed upon volume, is obtained by means of a stop watch. While the bell is descending, the pressure indicated by the water manometer, is read. This gives all the data required to compute the permeability in any units desired, or the time for the descent of the bell between two certain marks may be taken as the permeability.

The pressure of air with this apparatus as with the American Foundrymen's Association apparatus is dependent upon the total weight of the bell and all the weight attached to it. The pressure will remain constant, if the weight is constant, except for some very slight change, due to submersion of some of the mass of the side walls of the bell as it descends. As the

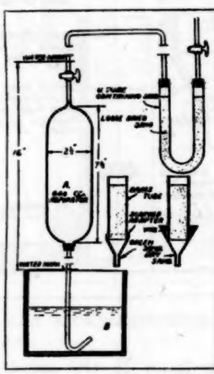


FIG. 16—SMALLEY'S ASPIRATOR APPARATUS

sand samples used in separate tests will vary the weight on the bell, with the apparatus described here, the pressure will vary accordingly. As a result manometer F is required.

Smalley's Aspirator Apparatus.

An apparatus used by O. Smalley[4] for determining the permeability of molding sands is shown in Fig. 16. The U tube

[4]The Foundry Trade Journal, May 31, 1923.

shown in place is used in testing dried loose sands. For moist sand a brass tube, shown in the same figure, is used with a rammer, shown in Fig. 17. The apparatus is described by Smalley as follows:

"The principle of the apparatus is to determine the time in seconds to draw a known quantity of air through a unit mass of sand. A, Fig. 16, is a copper vessel, rigidly fixed in a suitable clamp, open at both ends, with a cock attached at the top. Secured to the lower end by means of a rubber tube is a bent glass tube, of the form and dimensions shown. This dips into a jar of water of known capacity. The sand may be tested either in the loose or rammed state. After filling the copper vessel, A,

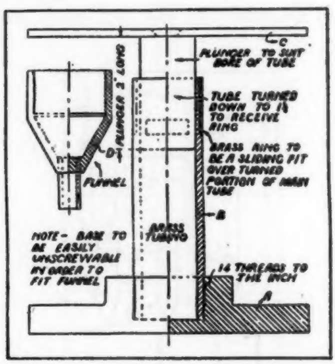


FIG. 17—DETAILS OF SMALLEY'S RAMMING DEVICE

with water by drawing from B, the sand tube is connected by means of a rubber tube. The time to empty A in seconds is recorded as the 'permeability figure.'

"Full details of the rammer are shown diagramatically by Fig. 17. A is a steel base plate. Into this is screwed brass tube B, on the top of which a slotted brass ring is placed. The sand is gently rammed into this tube by means of a ⅜-inch wood rod in the ordinary way to ½ inch from the top. Into this is placed the stem of plate C. Pressure is then applied, compressing as required. In the early stages of development of this apparatus the pressure was applied by means of a delicate

lever mechanism to a predetermined cone density test. After considerable experimental work, it was found possible to simplify the test by applying a presure of exactly 60 pounds and rotating six times. The weight removed, top plate C is withdrawn, the brass ring lifted away, and, by the aid of a spatula, the sand above the top of the slot is cut away. The brass tube containing the sand is removed from the base plate, and screwed into a cone-shaped adaptor, D, which is attached to the aspirator."

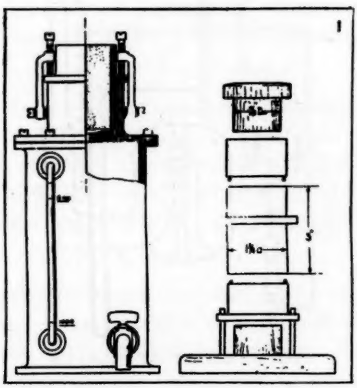


FIG. 18—CURRIE PERMEABILITY TESTER

A British Apparatus for Testing the Permeability of Sands.

In an article by E. M. Currie[5], attention is called to the apparatus for determining the permeability of molding sands, shown by Fig. 18. A permeability apparatus and a rammer are shown. The permeability apparatus is important to note, because it is constructed of cast iron, making it very rugged. It operates on practically the same principle as the apparatus pre-

[5]*The Preparation and Testing of Moulding and Core Sands,* The Foundry Trade Journal, December 13, 1923.

viously described. The rammer on the right side in Fig. 18 possesses some unsual features. It consists of a long brass cylinder with a flange in the center and split transversely into three sections. The three sections are fitted with dowels to hold them in line. The cylinder complete is placed on end and filled with sand, which is rammed with the wooden ram shown above the cylinder in Fig. 18. The three sections of the cylinder are then separated and the sand in the central section cut off evenly with its ends. The sand is tested in the central sec-

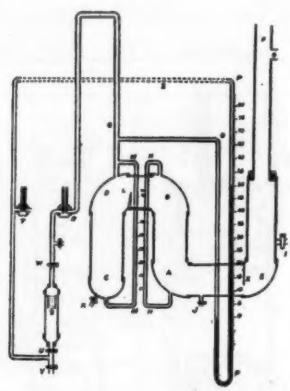


FIG. 19—KNAPP APPARATUS

tion by fitting this section into the permeability apparatus as shown. No details of how heavily the sand is rammed accompany the description by Mr. Currie. This method of ramming is one way of obtaining a constant length for the sand cylinder without the necessity of using a trial-and-fail method.

Minnesota Apparatus.

The permeability apparatus shown in Fig. 19 is described by G. N. Knapp[6]. It was used in an extensive survey of the molding sand resources of Minnesota. The apparatus is described by Mr. Knapp as follows:

[6]*The Foundry Sands of Minnesota*, Bulletin No. 18, Minnesota Geological Survey. 1923.

"The apparatus consists of a series of chambers made of large threaded iron pipe in which the air was compressed by admitting water into the chambers. The apparatus is connected directly with the city water system, which has a pressure of 65 pounds, thus insuring an ample supply of water as rapidly as may be needed. The water is admitted into the apparatus through a 2-inch gate valve at I. It passes through chambers EA and AB and into CD, each of which is 6 inches in diameter, compressing the air as it advances. A weir 6 inches across is provided at L, over which the water passes into chamber CD. A standpipe 4 inches in diameter is provided at F, open at the top, with an overflow for waste at G. The waste gate, G, is 50 inches above the weir L, which insures a uniform head of 50 inches of water, giving a pressure of about 4.5 pounds.

"The compressed air is conducted through a 2-inch pipe, Q, which extends 20 feet above the apparatus, returning to R, where wet and dry bulb thermometers are installed in the air line. From R the air is conducted downward through a common well cylinder, in which the sand sample to be tested is mounted at S.

"After passing through the sand S the air is carried upward and through a waste valve at T, in which another set of wet and dry bulb thermometers is installed. A water manometer, OPP, is connected with the air line Q and provided with a scale, graduated to 1/10 of an inch. The manometer registers the pressure, 50 inches, direct, and variations in presure can be read to 1/10 inch, or .2 of 1 per cent of the total pressure.

"Chambers AB and CD are provided with glass water gages, MM and NN, which show the height of the water in these chambers at all times. The volume of chamber CD was determined by measuring water into it when the apparatus was installed. The glass gage, MM, was provided with a scale, and the calibrations in half liters were marked on this scale as the water was measured into the chamber CD. The chamber CD holds 74 liters to the level of the weir L, which is the capacity of the apparatus. When in operation the amount of air that is

passed through the sample is registered at all times by the position of the water in gage MM.

"Waste valves are provided at K and J to empty the apparatus of water after a run is completed. A baffle at X serves to make the greater part of the air in chamber AE available for compression, and to prevent undue agitation in chamber AE when the city water under high pressure is admitted.

"Control valves are provided at U, V and W. The wet bulb thermometers at T and R have the bulbs wrapped with lamp wicking, and a small chamber filled with water is provided below the air line beneath the wet bulbs, in which the wicking is submerged, thus providing the wet bulbs with water to meet the needs of evaporation.

"The upper end of the waste pipe Y is connected with the upper end of the manometer P to guard against, and register any back pressure that might result from friction or otherwise when air is passed rapidly.

"The procedure in testing is as follows: The sand to be tested is mounted in the well cylinder at S; the valves U and V are closed; the valve I is opened, admitting the water into the apparatus rapidly, so that it overflows in considerable volume at G. The rise of the water in chamber AB is registered in the glass gage NN, and the rate water rises here naturally declines as the pressure increases. The manometer, OPP, records the pressure as it progresses. When the water in chamber AB reaches the level of the weir L, which is indicated by a calibration mark on the gage NN, the manometer is read. The valve U is then opened, allowing the compresed air to pass through the sample. When the water in chamber CD reaches the zero mark on gage MM the stop watch is started and allowed to run until the water in chamber CD, as registered on the gage MM, reaches the calibration 74, indicating that 74 liters of air have passed through the sand. The watch is stopped the instant the gage MM registers 74, so that the time is recorded to a fraction of a second. The valve I is then closed, and the valves J and K opened to empty the apparatus.

"The temperature of the room and the barometer is recorded at the beginning of each run, and the wet and dry bulb

thermometers at R and T are read three times or more during each run, viz.: the beginning, at the middle, and at the end of the run."

To express the permeability of a sand tested with this apparatus the time required to pass 74 liters of air through standard Ottawa sand was divided by the time required to pass 74 liters of air through the sand under test and the result considered to be the permeability of the sand in per cent. The method assumes the permeability of Ottawa sand, selected as the standard, as 100 per cent.

Cole's Permeability Apparatus.

A novel method of determining the permeability of a molding sand is described by L. Heber Cole[7]. This apparatus is

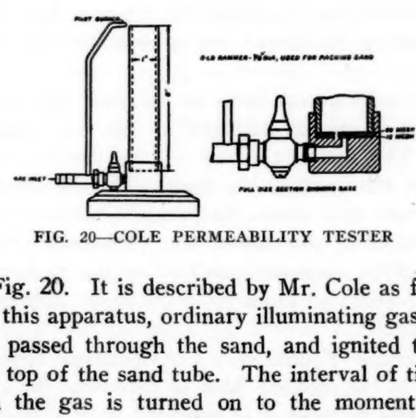


FIG. 20—COLE PERMEABILITY TESTER

shown by Fig. 20. It is described by Mr. Cole as follows:

"With this apparatus, ordinary illuminating gas at a definite pressure is passed through the sand, and ignited the instant it reaches the top of the sand tube. The interval of time required, from when the gas is turned on to the moment of ignition, is noted by a stop watch, thus determining the passing of the gas. Three tests are run on each sample, using fresh sand each time. The average time is taken as the permeability factor. The sand is packed uniformly in the cylinder by taking in a small quantity at a time (about 1 inch of sand), pressing it down for 5 seconds, using a 5-pound weight. When the cylinder is filled it is struck off flush on the top with a straight edge."

[7]Summary Report of the Mines Branch of the Canadian Department of Mines for 1916, Investigation of the Sands and Sandstones of Canada, Page 35.

This apparatus is supposed to have an advantage not possessed by any other apparatus. The assumption is that a gas, after having once flowed through a mass of sand, opens up channels in the sand, and, therefore, meets with less resistance to flow after the first instant of flow. This apparatus measures the resistance the first advancing front of the gas meets with, which is not done by other apparatus.

Determination of the Openness of Sand in the Flasks

An apparatus has been manufactured, and marketed under a patented name, which is taken into the foundry and used to determine the openness of the sand when it is already in the flask.

The principle of the apparatus is that a stream of compressed air is divided between two orifices through which it escapes. A manometer indicates the pressure back of the orifices. One orifice discharges into a short flexible tube with a metal tip.

To use the apparatus, it is set up near the flask and the air supply turned on and adjusted so that the manometer registers zero. The tip on the end of the flexible tube is then placed against the sand in the flask. This obstructs the flow through the tube and raises the pressure back of the orifices, which is indicated by the manometer. The more permeable the sand the lower the pressure indicated by the manometer. The manometer is calibrated to an arbitrary scale reading from 0 to 100.

The American Foundrymen's Association apparatus may also be taken to the molding floor to determine the openness of molds. For this purpose it is provided with a length of flexible tube with a tip, also an attachment for securing the tube to the lower end of the tube of the apparatus. Used this way the apparatus does not give permeability in standard units.

General Comment.

Each of the permeability apparatus described has been proposed as a general apparatus for foundry or laboratory use. Certain of these apparatus have distinguishing features, which

make them more desirable to use than other apparatus. It may also be possible to incorporate the desirable features of one apparatus with those of another to make an apparatus superior to both. There is perhaps none of the apparatus which can be operated as quickly and with as little trouble as can the American Foundrymen's Association apparatus, used with the orifice attachments. It is thus a highly desirable foundry apparatus. This apparatus is also a very accurate one, when used as a standard apparatus, making it very satisfactory for laboratory use. It is the latest one of all the apparatus described to be designed.

For much of the apparatus described in this paper glass has been the material specified. As any glass apparatus would be at a great disadvantage in any foundry where it would be subject to rough handling, metal construction would be better. Metal parts could be substituted for many of the glass parts of the various apparatus described and these be built almost entirely of metal. As an example, the Grubb apparatus has been redesigned by a firm dealing in foundry supplies and has been placed on the market in an all-metal form. Certain parts, such as manometer tubes and water gages, cannot, of course, be built of metal.

The author wishes to express his appreciation to Dr. H. Ries for the many helpful suggestions received during the study of the various permeability apparatus described and during the preparation of this paper. The author also wishes to express his appreciation for the co-operation of Mr. C. M. Nevin while studying the operation of several of the apparatus described in this paper.

The Relation of Water to the Bonding Strength and Permeability of Molding Sands

By CHARLES M. NEVIN, Ithaca, New York.

In former times, and even to a considerable extent at present, the amount of water required for tempering a sand has been and is left largely to the judgment of the molder or foundry foreman. However, there is now an increasing number of foundries where the water content of the sand is closely controlled, because it is realized that certain defects in castings are traceable to an incorrect moisture content. This, of course, is due to a recognition of the fact that all sands do not temper alike, and that each one gives the best results with one certain water content. Lack of knowledge of this fact has no doubt sometimes resulted in a new sand being condemned, because it was tempered with the wrong amount of moisture.

The cause of the variation in bonding strength and permeability with changing water content is a matter of great interest as well as practical value, and in the present paper an attempt is made to explain this.

Ries and Rosen[1], during their study of Michigan molding sands, showed that the permeability of a foundry sand varied with the water content, and that there was one percentage of water with which each sand showed the maximum permeability. This percentage they called the optimum or "best" water content.

Ries and Nevin[2] pointed out that the same thing held true for the bonding strength and that for each molding sand there is usually one certain percentage of water with which the best cohesiveness is developed and that either more or less water usually weakens the sand.

[1]Ries & Rosen—Mich. Geol. Survey—Ann. Rept. 1907, p. 50.
[2]Ries & Nevin—The Cohesiveness Test of Foundry Sands. Trans. Amer. Found. Assoc. Vol. 31, 1924.

Sometimes the same amount of water develops both maximum permeability and cohesiveness and the peaks of the permeability and cohesiveness curves will then agree. In other cases this relation does not hold true.

At first glance it would seem as though the former practice of adding just enough water to make the sand cohere is all right, but with the recently devised standard testing methods it has been demonstrated that many sands reach their best strength and permeability with the addition of 2, 4 and even 6 per cent of water above the point where formerly they might have been considered correctly tempered.

This additional water does not appear to clog up the pore space and make the sand tight, as thought by some, but in reality, up to a certain point, opens it up. Why this should be, as well as the controlling factors that influence the effect of water on the bonding strength, is the main theme of this paper.

The Bond.

Undoubtedly the bonding strength is a very important and not thoroughly understood property of molding sand. Yet the presence and behavior of the bonding material is the criteria that distinguishes molding sand from all other sand. Its destruction by burning out during casting immediately returns the sand to the waste heap, a molding sand no longer. Too much bond, too small an amount of bond, the wrong kind of bond or the improper tempering of the bond, is undoubtedly the daily cause of foundry losses. In fact, for this reason, foundrymen have become skeptical of drawing on new and untried sources of supply.

That the bonding material is not necessarily clay, has been appreciated for some time, yet the terms "clay bond" and "clay substance" are still rather widely used. Our present knowledge tends to show that this bond is usually a mixture of oxides and hydroxides of iron, alumina and silica in a state of extremely fine division. So we call them colloids and think of them as having a net-like or spongy arrangement, with the inherent ability to take up many times their volume of water.

Upon subjection to sufficient heat these colloids are destroyed,

their ability to take up water and become sticky is lost, and the sand is said to be "deadburned." Fortunately, at a temperature somewhat below the complete dehydration of these colloids, no marked effect seems to be produced. Thus, if the bond is not subjected to too high a heat it will rehydrate, become sticky again and can be used over.

It is this important critical temperature, which varies for each type of colloidal bond, that doutbless makes some sands stand upon better than others under foundry conditions. Many clay bonds will stand a relatively high temperature without breaking down, but they have the unfortunate habit of partially sintering, and in this condition the colloidal property of taking up water and forming a sticky mass is lost. Fine grinding will often restore it. On the other hand, a hydrated iron bond will rehydrate better than any other type, although very high temperatures are unfavorable to its use. A happy combination of hydrated colloidal iron and clay, such as the chemical analyses of many of the well-known molding sands indicates, gives a long-lived bond, one that will easily rehydrate.

Arrangement of the Bond.

Many molding sands seem to have the bond existing in two forms, since, after repeated washings of the sand grains and even treatment with dilute HCl acid, a thin pellicle of iron oxide still remains, giving the sand grains a rusty tint. This film would appear to be dehydrated and incapable of taking up water or dye solutions. C. W. Holmes[3] has remarked on this two-form existence of the bond and speaks of—

1.—A mobile or hydrated bond which is capable of transference from one sand grain to another.

2.—A static bond which is fixed to the surface of the sand grains and forms a hold upon which the mobile bond may be easily spread and displayed to the best advantage for mechanical strength.

Many molding sands show this twofold characteristic of the bond. A small amount of the static bond has a greater tendency to strengthen a sand than several times that amount of

[3]C. W. Holmes, Iron and Steel Inst. Sept., 1922.

mobile bond on smooth grains of silica. This is one reason why an artificially blended molding sand of loam and clean silica grains often does not have the feel of a natural product and will give clean sand grains upon washing.

Effect of Water on the Bond.

When the molding sand is dry most of the bonding material lies loosely in the interstices between the sand grains. Thus the permeability of a dry molding sand is low because of the clogging up of the pore spaces, and, of course, since the bonding material is not sticky in this condition, the cohesiveness is low also.

With the addition of water the mobile part of the bond becomes sticky, swells up and wraps itself around the sand grains, thus moving out of the pore spaces. Naturally, both the permeability and cohesiveness increase. So with just the right amount of water the bond will be evenly spread around the sand grains, leaving the pore spaces free for easy venting, and, because of its sticky character with this amount of water, the cohesiveness will also be high.

If too much water is added the bond will not be able to take care of it and free water will fill the pore spaces. Also the bond will become weaker, just as an overtempered green clay brick does, and slide from the sand grains back into the pore spaces. So it is evident that too much water will decrease both the cohesiveness and permeability of molding sand and is just as great an evil as too little water.

It is interesting to note here that many molding sands, when correctly tempered, will dry out completely without the sand grains changing position. This was proven by fifteen and twenty-minute exposures of tempered molding sand to the photographic light, during which time the bond dried out completely without leaving any evidence of movement on the photographic plate. This is rather remarkable, when it is remembered that the bond had swelled up and expanded during tempering. If the sand had been much overtempered, so that free water existed in the pore spaces, doubtless a shrinkage movement would have spoiled the negative.

Under the microscope this movement of the bond upon the addition of water is very clearly seen, so that the critical point of correct tempering can be determined very easily and quickly in this manner. Indeed, it is quite possible that some day the microscope may serve as a very efficient agent in foundry control work and obviate some of our present more troublesome methods.

In order to show this graphically a few photomicrographs are here presented, but it should be understood that much of the detail has been lost. To really appreciate this action of the water on the bond and permeability, a comparison eyepiece and two microscopes should be used so that the details of the arrangement of the grains due to differences in water content, can be seen side by side.

A recent paper by Dietert[4] gives in some detail the proper methods to use in taking photomicrographs of molding sand, but for the following illustrations, a simple inclined illumination was used with an ordinary microscopic lens, the time of the exposure often lasting over fifteen minutes. With stronger illumination, a longer focus lens and an iris diaphragm, better results would have been secured.

Fig. 1 to Fig. 3, represent a No. 3 Albany sand tempered with increasing amounts of water to show how the grains agglomerate. This sand is not compacted, but is loose, being taken from the different tempering piles. More compounding of the grains is noticeable with each increase of the water content.

Fig. 4 to Fig. 6 represent a Millville gravel tempered with different amounts of water, with the maximum permeability and cohesiveness obtained with a water content of 7 per cent. The undertempered sand in Fig. 4 is typically of a "grainy" or "smallpox" appearance. The correctly tempered sand in Fig. 5 has the bond more uniformity spread, and for this reason with the same amount of exposure as given to Fig. 4, prints out much brighter. Fig. 6 shows the usual "dough" or "molasses"-like appearance of a partially overtempered sand. The bond has

[4]H. W. Dietert, Applied Photo-micrography of Foundry Sands Trans. Amer. Found. Assoc. Vol. 31, 1924.

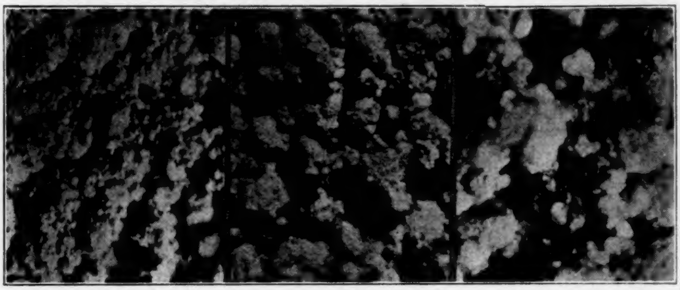


FIG. 1—6% WATER　FIG. 2—8% WATER　FIG. 3—10% WATER
LOOSE ALBANY NO. 3 SAND FROM TEMPERED HEAPS—MAGNIFICATION 12X

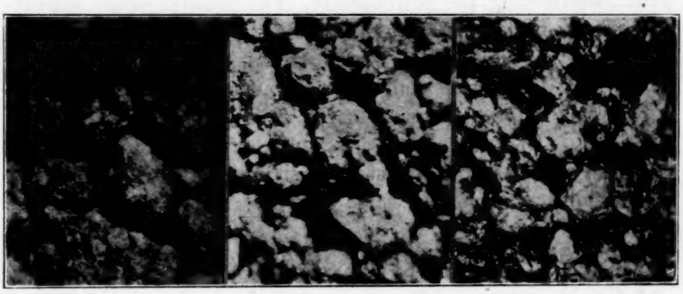


FIG. 4—4½% WATER　PERMEABILITY...150　COHESIVENESS...185
FIG. 5—7% WATER　PERMEABILITY...340　COHESIVENESS...380
FIG. 6—10% WATER　PERMEABILITY...135　COHESIVENESS...210
A FINE MILLVILLE GRAVEL WITH STANDARD COMPACTION— MAGNIFICATION 12X

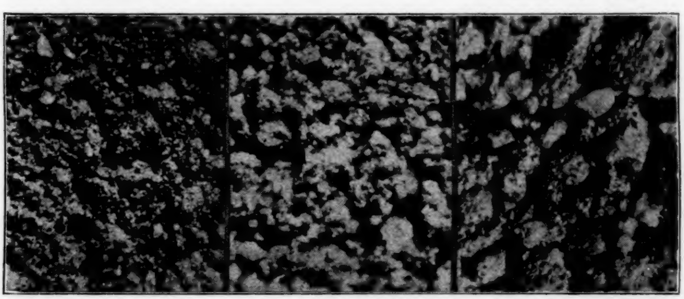


FIG. 7—6% WATER　PERMEABILITY 16
FIG. 8—8% WATER　PERMEABILITY 50
FIG. 9—10% WATER　PERMEABILITY 36
A NO. 3 ALBANY SAND—MAGNIFICATION 12X

not been weakened enough to entirely leave the sand grains, but it has started to run.

The resulting changes in permeability and bonding strength are self-explanatory and distinctive. The permeability was obtained just before the photograph was made, the microscope being afterward focused on the end of the permeability test piece. The cohesiveness figures were obtained from an additional amount of the same sample.

As a final illustration, Fig. 7 to Fig. 9 are presented as especially representative of this reaction of a molding sand with insufficient, correct and excess amount of water of tempering. These pictures were made on the compacted surface immediately after determining the permeability. The grainy, rough appearance of the undertempered sand in Fig. 7, and the overtempered sand in Fig. 9, with its large percentage of bond-free sand grains, are in striking contrast to the evenly coated, nicely arranged condition of the sand in Fig. 8, which has been correctly tempered. In fact, these three photographs are so entirely different that it seems almost impossible that the same sand, the same compaction and the same enlargement are common to all.

Relation of Water to Strength and Venting.

Coming now more directly to the relation between the bonding strength and permeability, when a molding sand is tempered with varying amounts of water, one of three alignments is usually developed.

1.—The maximum bonding strength is developed with the same amount of water as the maximum permeability—that is, the peaks of their plotted curves agree.

2.—The maximum bonding strength is developed with less water than the maximum permeability.

3.—The maximum bonding is developed with more water than the maximum permeability.

Before considering these three relations further, it should be pointed out that the permeability test is more delicate than the cohesiveness test, and, therefore, some disagreement in the alignment of their curves may be attributed to this fact. This is especially true with certain sands where the cohesiveness does

not seem to change much, even with quite a variation in the amount of tempering water.

Moreover, the cohesiveness test is handicapped in not being able to give consistent breaks for those sands that require only a small amount of water to develop their strength. This may perhaps be due to a nonuniformity of tempering when such small amounts of water are used, but even with special care, the bars tend to flaw and give unreliable results. Very likely, if the above disturbing factors did not exist, more molding sands would come under Class 1, as they might perhaps develop their best permeability and strength with one and the same percentage of water.

In studying these water tempering relations, the data from the tests of over two hundred molding sands were used. These sands represent practically the entire range of molding sand types and were secured from New Jersey, Michigan, Virginia, Alabama, Pennsylvania and New York. The tests for permeability and cohesiveness were conducted according to the standard methods recommended by the American Foundrymen's Association, and, therefore, give dependable results.

Considering this entire series we find that 33 per cent of the molding sands fall in Class 1, and show an agreement of the permeability and cohesiveness; 56 per cent come under Class 2, that require less water for the maximum cohesiveness than for the maximum permeability; 11 per cent represent Class 3, that require more water for the best cohesiveness than for the best permeability.

The photographs already presented give a general idea of the movement and arrangement of the bonding material and show why there should be a rise and fall in the values of both the permeability and cohesiveness. For a more adequate explanation, however, it would seem necessary to consider the influence of the grading of the sand grains and the amount of fine silt, as well as the character of the bonding material.

Taking up each one of the three general classes already outlined, an attempt will be made to explain the conditions existing and their effect on the cohesiveness and permeability. These explanations are offered as suggestions merely, as it is

thought that the investigation of the effect of water on molding sand has not yet reached the stage where entirely trustworthy conclusions can be drawn.

Class 1—Optimum Water Content the Same for Cohesiveness and Permeability.

As already intimated, we might find that half of the molding sands fall in this class, if the bond test were more delicate. The following examples in Table 1 will serve to illustrate the usual character of the sands in this group.

The giving of further examples would be to no purpose, as this agreement in tempering for cohesiveness and permeability is not restricted to one certain water content, but may occur with any amount of from 3 to 15 per cent, depending on the particular sand. It is as prevalent in fine brass sands as in coarse Millville gravel, in strongly bonded sands as in the weaker sands, and sands with either high or low permeability seem to exert no restrictive influence. Thus any grade of molding sand may come under this general class if it has the right kind of bond.

Table 1.—Agreement of Optimum Water for Both the Cohesiveness and Permeability

State	Per cent water	Cohesiveness	Permeability	Per cent water	Maximum cohesiveness	Maximum permeability	Per cent water	Cohesiveness	Permeability
New Jersey.	2.8	160	72.0	3.9	182	93.0	6.0	132	80.0
Michigan ...	4.3	174	21.8	6.4	207	38.0	8.4	204	34.0
Alabama	4.8	138	66.4	6.5	304	73.8	8.5	235	60.2
Virginia ...	7.8	314	93.1	9.5	400	124.2	10.4	314	89.6
New York...	11.6	186	7.0	13.1	202	10.0	15.4	190	7.5
New York...	3.4	110	63.0	5.8	126	111.0	8.0	98	105.0

By the right kind of bond is meant material of such a nature that, with the proper tempering water, the sand grains are uniformly and evenly coated. With less than the proper amount of water the bonding substance is not evenly distributed, the coating around the grains will be uneven and grainy in appearance, the greatest cohesiveness will not be developed and some of the bond will be left in the pore spaces, giving a lowered permeability.

With the correct amount of tempering water, because of the resulting even coating around each grain, the greatest amount of bearing surface will be formed and the maximum cohesiveness developed. At the same time the largest amount of pore space will be left open and the best permeability developed.

An excess of tempering past this point will soften and weaken the bonding material, and tend to permit it to flow back into the pore spaces. Obviously, the permeability and bonding strength will then both decrease, although not necessarily at the same rate.

Class 2—Maximum Cohesiveness Is Developed With Less Water Than the Maximum Permeability.

Of a total of 56 per cent of the molding sands which fall into this class with the present methods of testing, almost one-

Table 2.—The Cohesiveness Requires Less Water to Develop the Maximum than the Permeability Does

State	Per cent water	Cohesiveness	Permeability	Per cent water	Maximum cohesiveness	Permeability	Per cent water	Cohesiveness	Maximum permeability	Per cent water	Cohesiveness	Permeability
New York.	4.1	197	..	6.0	247	24	8.3	188	44	10.2	...	35
New Jersey	3.1	183	55	4.1	268	62	6.1	248	80	8.2	189	55
Virginia ..	...	...	..	4.0	196	33	6.3	159	41	9.0	...	39
Alabama...	3.8	174	10	6.0	175	21	8.1	158	25	9.9	...	25
New York.	4.0	146	14	6.0	173	68	8.0	127	169	10.1	...	133
Virginia ..	5.0	255	60	6.0	275	86	6.3	267	111	8.0	223	90

third of them develop their maximum cohesiveness with the lowest possible per cent of water with which a consistent break for the bar test may be obtained. At this same point the maximum permeability is also often developed, but even so, it was thought best to include such sands here rather than in Class 1, where they may very likely belong, because there is no certainty that this first point is the real maximum for the cohesiveness.

The examples in Table 2 will serve to illustrate the character of typical sands in this class.

Even a quick survey of this table should convince any foundryman of the importance of knowing just what water content will give the best venting and strength. It should be also

noticed that the permeability often increases very quickly with a slight change in the amount of water, accompanied sometimes by a very decided weakening of the bonding strength. With such a sand it would depend on the type of casting to be made as to whether it would pay to temper toward the maximum strength or toward the best venting.

The reason why the maximum cohesiveness is developed with less water than the maximum permeability is perhaps due to the difference between the adhesive and cohesive properties of the type of bond that is common to sands of this group. That is, the bonding material would tend to lose its coherence or ability to stick together and resist rupture, before it would lose its adhesiveness or ability to coat the sand grains.

With such an explanation the addition of water would tend to give a break between the bonding particles long before these particles lost their ability to adhere to the quartz sand grains. As long as the bonding material remained on the sand grains and soaked up the tempering water, the permeability would not start to decrease, even though the maximum for the cohesiveness had been passed.

From a previous study with dye solutions, it is thought that the collodial bonding material in this group of molding sands is mainly of a basic nature, and, therefore, would tend to be adsorbed by the unlike acid quartz grains. Some such explanation must be advanced to explain the wrapping of the bonding material around these grains upon the addition of water, no matter which one of the three general classes is being considered.

In this connection, it may be of interest to mention that during the microscopic study of the effect of water on molding sands, it was noticed that feldspar particles, especially if weathered, took up very little, if any, bonding material, no matter what tempering was used. So it is thought that the property of adherence is a very important one and that the arrangement of the bonding material around the sand grains is very likely due to colloidal adsorption.

Class 3—The Cohesiveness Requires More Water to Develop a Maximum Than the Permeability Does.

Only 10 or 11 per cent of the molding sands studied show such a relation, although a large number of silty core sands, which were studied at the same time, show a similar tempering peculiarity. That such a condition is unusual, is evidenced by the fact that the total percentage of occurrences is very small and that no well known or important molding sands are found in this group.

First, considering the silty core sands, of which Table 4 is a typical example, it will be noticed that a very small amount of bonding material is present. In a sand such as this, the small amount of bonding material present would be immediately overtempered by the addition of water, and, therefore, the pore spaces would become clogged with water and fine silt, and the permeability would show a continual decrease. The small increase in cohesiveness could be attributed to the dampening effect and the surface tension caused by the addition of the water.

Considering a true molding sand of this Class 3, the illustration, as shown in Table 3, might serve. The explanation of the reaction of this peculiar type of molding sand to water, is difficult. A small amount of bonding material and a relatively large amount of —270 mesh are often typical of this group, and are, therefore, suggestive. Perhaps the real explanation lies in a large percentage of inert material that is often included in the so-called "clay substance."

Table 3.—Test of a Typical Molding Sand in Class 3

Fineness Test		Per cent water	Cohesiveness	Permeability
6	0.00	4.0	too dry	21.0
12	0.00			
20	.04	5.6	124	22.0
40	.32			
70	1.06	7.9	124	18.4
100	4.16			
140	15.04	9.6	133	13.8
200	21.64			
270	28.64	11.9	142	13.8
thru 270	20.76	13.2	132	13.8
clay	7.88	15.1	too wet	10.7
	99.54			

If there happens to be a large amount of such inert material, then the active bonding colloids would be quickly overtempered upon the addition of even a small amount of water. The further increase in cohesiveness upon the addition of water, linked with a usual constant decrease in permeability, might be attributed to the surface tension of the water on the sand and silt grains. The finer the grain size, the more effective this surface tension seems to be.

Of course, one could say that the adhesion of the bond to the sand grains was not very strong, and that the best cohesion of the bonding particles to each other required a lot of water. Perhaps an acid type of colloidal bond such as a hydrated colloidal silica, in contrast to the usual basic type of colloid,

Table 4.—Test Sheet of a Michigan Core Sand

Fineness Test		Per cent water	Cohesiveness	Permeability
6	.36	1.6	..	341
12	4.92			
20	6.46	3.9	69	326
40	28.44			
70	47.42	5.4	73	300
100	8.56			
140	2.08	7.7	74	253
200	.44			
270	.28	10.0	too wet	too wet
thru 270	.36			
clay	.64			
	99.98			

might be the solution of this low adhesion to the acid sand grains and the high optimum water for cohesive strength.

However, it would seem best to await the final answer to this problem until some work has been done on separating the amount of inert, fine silt from the active bonding material.

Conclusions

It is evident that the best sands for foundry practice are those that develop their maximum cohesiveness and permeability with the same amount of tempering water. Among such sands certain ones show a rather small variation in both permeability and cohesiveness over quite a range in the amount of tempering water. These latter sands are ideal and will stand the abuse that quantity machine production entails.

Other sands of this class show a rapid change in either the permeability or cohesiveness, or sometimes in both, with a small

variation in the water content. Such sands require careful watching, so that the tempering of the heaps may always give the best results.

Those sands which develop their maximum cohesiveness with one amount of water and the maximum permeability with another, always present something of a problem, as the choice must be made as to which of these physical properties to sacrifice, especially if there be several per cent difference in their optimum water contents.

In conclusion, it is hoped that this discussion of the relation of water to the cohesiveness and permeability will emphasize the practical worth of knowing how each sand heap is daily behaving on the floor and the necessity of constant control tests in order to get the best possible performance.

The writer wishes to acknowledge his obligation to Dr. H. Ries of Cornell University for his many helpful suggestions during the preparation of this paper.

Notes on the Grading of Sands With Special Reference to Albany Sands

By Charles M. Nevin, Ithaca, N. Y.

During the past year the writer has had occasion to make a study of the sand deposits of the Hudson River region, of which Albany is the center, the investigation being part of the co-operative work entered into between the various State Geological Surveys and the Joint Molding Sand Research Committee.

The field work in this case was carried on for the New York Geological Survey, and the samples were studied at the sand testing laboratory at Cornell University under the auspices of the American Foundrymen's Association.

As a result of the field work and the study of the data obtained in testing the sands, certain views regarding the grading of sands are suggested, which it is hoped may be favorably received, or at least stimulate discussion.

Sand Deposits of the Albany District

Before taking up the main theme of this paper it may not be out of place to make a few brief statements regarding the occurrence of the sands in the Albany district.

Occurrence and Association

The present production of Albany molding sand extends approximately from Glenns Falls on the north, to Marlboro on the south and has a variable width along both sides of the Hudson River as shown in Fig. 1. About one hundred separate strippings were being worked during the summer of 1923, the largest operations occurring in the central region near Albany, although the shipping centers show a wide distribution, covering practically the entire area.

Real molding sand constitutes only a very small part of the total deposits, but fortunately it is always found next to the surface soil, unless covered by recent sand dunes. Associated with these scattered molding sands are found large deposits of sharp, open, gray building sand. A typical occurrence is shown in Fig 2, where a moving sand dune has covered the soil layer

FIG. 1—DISTRIBUTION OF THE ALBANY MOLDING SAND AND ITS RELATION TO THE HUDSON RIVER SHALES

and underlying molding sand which in turn, with depth, changes to the open, sharp, gray building sand.

The dune sand shows a marked similarity to the molding sand in the shape and size of the quartz sand grains, but differs from the latter in the presence of undecomposed shale particles

and the absence of coloring due to iron compounds. Also these shifting sand dunes lack the bonding strength of the true molding sand.

Since the sharp, gray sand is usually covered with soil, molding sand or sand dunes, its distribution and extent may be easily overlooked. Consisting of angular particles of metamorphic rocks, essentially phyllites, slates and quartzites, this

FIG. 2—TYPICALLY CROSS-BEDDED DUNE SAND, UNDERLAIN BY 10 IN. SOIL AND THE MOLDING SAND LAYER. "A" DUNE SAND "B" SOIL AND "C" MOLDING SAND

gray to black sand is in marked contrast to the yellow-brown molding sand into which it often grades with depth. Moreover the sharp gritty feel of the gray sand easily distinguishes it from the associated molding sand which has a characteristic smooth,

velvety feel. This difference in feel and color is used by all the field foremen in judging how deep to dig their molding sand.

Characteristics

An outstanding characteristic of the Albany molding sands is that within short distances they show great variation in practically all their physical features.

The thickness of the true molding sand varies from a few inches to eight feet or more, depending on the origin and local conditions. Fig. 3 illustrates the usual thickness of eighteen

FIG. 3—BANK OF THE NORMAL LAYER TYPE OF MOLDING SAND. THIS LAYER ROUGHLY FOLLOWS THE TOPOGRAPHY

inches, which lies immediately under the soil and rises and falls with the topography. This layer type is so widespread that it makes the average thickness of the molding sand for the entire Hudson Valley District about twenty inches, thus forming quite a contrast to some of the New Jersey and Virginia deposits which are thick enough to permit the use of steam shovels.

Perhaps the texture or fineness has done more than any other one thing to make the Albany sands well known, and yet this grain size, as found in the field, is extremely variable. In

an area no larger than ten acres all the grades from No. 0 "fine" to a No. 3 "coarse" are often found. Indeed, no matter what grade is being dug, sudden changes in texture are the usual thing and seem to follow no set rule.

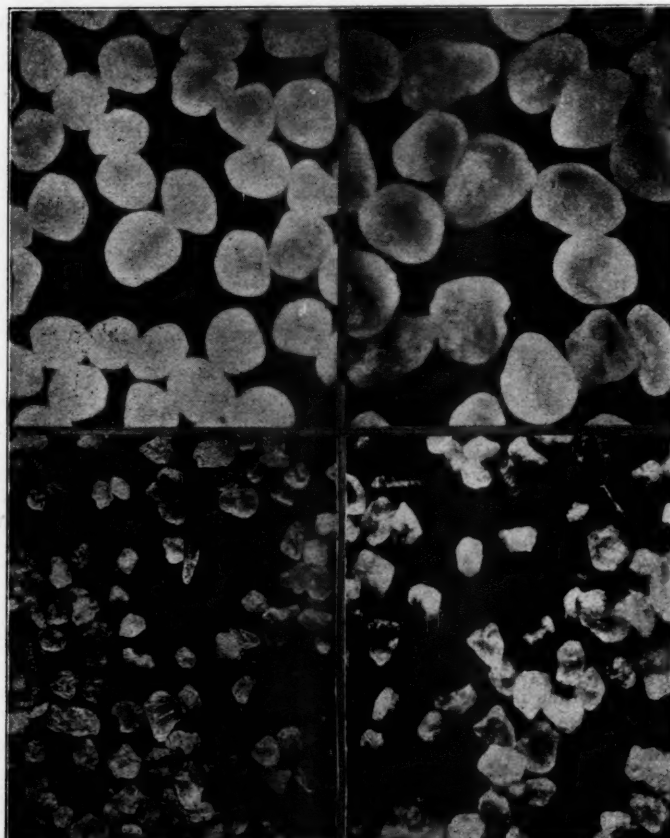


FIG. 4—TYPES OF SAND GRAIN. UPPER LEFT ROUNDED WATER WORN GRAINS OF STANDARD OTTOWA SAND, MAGNIFIED 12X,—UPPER RIGHT SAME SAND, MAGNIFIED 16X,—LOWER LEFT SUB-ANGULAR GLACIAL WORN ALBANY SAND, MAGNIFIED 12X,—LOWER RIGHT SAME SAND, MAGNIFIED 16X

The bonding strength or cohesiveness also changes with the same apparent disregard of law and order. Under heavy vegetation or down the gentle slopes of the hillsides the deposits are usually stronger in bond but exceptions to this are numerous. Under the microscope, when washed free of this bonding material, the individual sand grains show a pronounced angular to sub-angular outline, as illustrated in Fig. 4. This suggests a clue to the possible origin as water-worn sand grains have a rounded form in contrast to the sub-angular grains associated with conditions of glacial erosion and deposition.

Origin

When writing about the unconsolidated deposits on the surface of our Northern States it is usually necessary to consider glacial conditions, and the deposits of the Hudson Valley form no exception to this general rule. Although the last advance and retreat of the great Pleistocene ice sheet occurred twenty thousand years ago, more or less, it is largely responsible for the present molding sand production of this district.

Sweeping down from the north, bearing a tremendous load of ground up rock debris scoured from Canada and the Adirondacks, the ice completely overran the Albany district. The fact that the soft shales and slates of the Hudson Valley were easily plucked by the moving ice and formed a large percentage of its burden when it became stagnant in the molding sand territory, is noteworthy.

The broad general fact that the retreat of the ice was very irregular, and that the normal drainage was impeded by glacial conditions to such an extent that large lakes were formed, should be emphasized. One of these lakes named Lake Albany, formerly covered the molding district and in it were laid down the sands that are of present importance.

Although the glacial forces furnished the material, it required the further influence of natural agencies to develop the proper physical conditions necessary to make a good molding sand. Briefly, the ordinary processes of surface weathering are thought to have changed the easily attacked particles of shale

and slate into a clayey substance which now forms the bond of the molding sand.

In other words, the active dune sands and especially the sharp gray sand are potential molding sands, but lack the proper physical condition given by years of weathering. So the associ-

FIG. 5—EXCEPTIONALLY THICK DEPOSITS OF MOLDING SAND WHICH ARE INTERBEDDED WITH LENSES AND LAYERS OF SHARP BEACH SAND (A)

ation of these sands is really a genetic one and the sharp gray sand may be thought of as the "mother sand."

If we accept this manner of origin, the eighteen-inch layered form of the Albany sand would represent the usual depth

of weathering. Also the constant variation in the strength of the bond could be attributed to depositional differences in the make up of the "mother sand" as well as to differences in the condition of weathering.

On the other hand, the occasional deposits which extend to a depth of eight feet or more, always mixed with lenses of sharp beach sand, are thought to have been deposited as a molding sand and hence do not merely represent unusually deep weathering. These thick deposits were formed by the scouring of the molding sand from the surrounding hills, during the reestablishment of the Hudson River drainage and are illustrated in Fig. 5.

In closing these remarks on origin it might be well to emphasize that the making of the bond was a matter of several thousands of years, that it was a very complicated process and that it is still going on today very slowly.

Having now briefly touched on the origin and occurrence of the Albany sands we are in a position to better understand some of the peculiarities of the physical properties, the discussion of which is the real theme of this paper.

Standard Tests

While tests of the Albany and other molding sands have appeared from time to time, a satisfactory comparison of these tests could not be made as they were not all carried out in the same manner, but since the American Foundrymen's Association has recommended several standardized methods for determining the properties of molding sands, it is now possible to get concordant results.

Incidentally, the development of these tests has also permitted the examination of untried sands, with the expenditure of much less time and money than was formerly possible. In fact, we might say that the whole subject of the behavior of molding sands and the governing factors that make some sands so far superior to others, could not be intelligently studied until standard testing methods were developed.

Table 1

Fineness Test

Sample Number	On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Per cent Clay	Total
	Per cent Sample Remaining On or Passing Through Screens											
209	.....	.14	.06	.26	1.16	1.28	2.26	4.94	21.84	47.68	21.12	100.74
221	.....	.38	.16	.26	1.78	2.98	4.54	7.08	20.80	42.34	20.06	100.38
231	.....	.18	.10	.22	.44	.80	2.80	7.18	25.60	44.66	18.42	100.40
251	.....	.04	.06	.04	.54	1.60	6.34	8.98	19.58	39.62	24.08	100.38
253	.....	.20	.12	.22	.62	1.28	5.56	8.74	19.14	37.34	27.00	100.22
254	.....	.26	.12	.32	.86	2.44	5.88	12.68	31.52	33.00	13.08	100.16
203	.....	.04	.08	.20	1.30	3.16	7.58	10.86	27.50	34.58	14.68	99.98
206	.....	.04	.10	.42	3.50	3.04	3.54	4.38	16.08	44.72	18.92	99.74
207	.30	.38	.18	.30	2.12	4.92	8.50	12.42	23.64	34.08	12.76	99.60
232	.....	.22	.20	.12	1.10	4.78	18.16	22.14	26.68	17.22	9.20	99.82
238	.....	.04	.02	.12	.62	2.20	7.80	12.04	26.42	32.74	18.24	100.24
240	.....	.....	.10	.34	1.02	4.48	11.70	15.82	27.68	26.64	12.26	100.04
241	.....	.....	.04	.32	1.06	4.16	15.04	21.64	28.64	20.76	7.88	99.54
244	.....	.02	.02	.02	2.48	4.02	13.30	18.60	19.54	22.68	19.34	100.02
249	.....	.....	.06	.02	1.92	3.46	12.36	16.48	19.34	26.54	19.52	99.70
255	.....	.04	.12	.50	2.70	3.08	5.50	12.10	28.68	33.92	13.52	100.16
258	.....	.06	.12	.40	3.44	4.50	4.92	5.34	18.56	46.66	16.00	100.00
360	.....	.16	.08	.54	3.70	1.98	1.88	3.90	18.10	47.40	22.12	99.86
361	.....	.16	.22	.42	2.32	1.36	2.68	5.56	23.04	46.76	17.10	99.62
215	.....	.08	.12	.28	2.48	9.48	22.50	24.50	21.16	13.52	6.46	100.58
228	.....	.10	.14	.44	6.50	15.06	16.16	14.98	18.86	17.68	9.96	99.88
239	.....	.....	.06	.16	4.32	16.90	19.18	13.12	15.80	16.02	14.18	99.74
250	.....	.16	.16	.30	4.76	8.08	11.12	10.98	17.10	23.98	24.00	100.64
259	.....	.04	.08	.12	.50	6.74	29.34	21.44	22.18	15.28	4.46	100.18
260	.....	.22	.10	.40	1.88	10.24	27.12	19.46	16.16	14.10	10.24	99.72
364	.....	.06	.10	1.22	10.22	9.92	11.30	11.10	16.98	23.48	15.78	100.16
369	.....	.20	.16	.36	2.36	11.08	20.34	14.64	19.04	22.04	9.70	99.92
211	.....	.12	.04	1.04	24.68	21.94	18.30	11.98	10.24	6.10	5.40	99.84
213	.....	.46	.64	2.18	11.10	14.96	15.78	13.50	14.84	13.88	12.30	99.64
246	.....	.44	.34	.50	15.04	25.60	16.14	7.52	8.56	11.70	13.88	99.72
256	.....	.04	.10	1.60	22.24	12.24	8.64	10.20	18.40	15.88	10.88	100.20
362	.14	.82	.14	1.64	17.16	7.62	5.20	6.90	16.62	28.69	14.68	99.56
365	.....	.20	.18	1.46	17.00	15.42	12.74	9.76	13.78	16.14	13.22	99.90
370	.....	.....	.02	1.00	26.50	22.98	11.40	6.10	6.32	9.06	16.70	100.08
371	.....	.....	.02	.72	19.68	20.18	14.50	8.26	9.46	11.40	16.70	100.92

Table 1—*(Continued)*

Fineness Test

Sample Number	Per cent Sample Remaining On or Passing Through Screens On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Thru 270	Per cent Clay	Total
204	.24	.24	.20	3.86	46.44	18.86	7.62	3.50	3.46	6.14	8.72	99.38
205	.12	.50	.90	.82	52.38	7.64	4.30	2.90	4.98	10.84	15.12	100.50
208	.....	.22	.52	2.00	29.16	15.64	12.80	8.68	12.14	10.78	7.70	99.64
212	.04	.18	.36	5.70	28.90	15.86	11.80	8.52	11.16	8.40	9.26	100.18
214	.14	.16	.10	1.74	35.84	20.50	12.94	6.78	6.78	7.44	6.92	99.84
216	.....	.36	.34	2.60	44.74	17.30	9.02	4.54	4.94	6.30	9.92	100.06
245	.20	.90	1.16	7.06	37.28	16.82	9.02	4.02	3.80	7.34	12.10	99.70
248	.....	.32	.70	3.96	56.74	11.18	5.44	2.74	3.40	6.50	10.06	100.04
261	.....	.98	2.62	10.08	22.70	18.32	10.56	6.56	8.18	10.34	9.82	100.16
257	.12	.64	.68	8.74	36.24	7.56	5.08	5.60	12.22	12.62	10.60	100.10
262	.14	.22	.68	6.20	33.64	18.84	10.78	5.34	4.94	7.68	11.38	99.84
263	.30	.82	.80	8.00	28.44	19.50	10.94	4.58	4.44	7.88	14.24	99.92
363	.....	.14	.12	3.88	30.98	11.04	4.76	4.26	9.00	21.74	13.82	99.74
210	.46	.96	1.32	19.14	41.56	5.26	3.08	1.86	2.96	7.60	15.76	99.96
217	.76	2.00	3.30	18.96	32.20	4.34	2.62	3.40	5.62	12.14	14.58	99.92
218	.78	1.42	2.30	16.50	53.16	3.22	1.50	1.58	2.74	6.34	10.60	100.14
219	.38	2.24	2.64	5.58	64.08	5.64	2.18	1.50	1.98	4.80	9.18	100.12
220	.64	1.48	2.08	23.20	42.70	4.30	2.00	1.80	3.14	7.10	11.34	99.78
247	.24	2.88	2.94	5.50	52.80	6.72	2.88	1.54	2.58	7.58	14.50	100.16
252	.60	.74	2.46	1.94	63.00	4.40	1.98	1.30	2.92	8.70	12.74	100.78

Properties Studied

The properties of the molding sands which were studied, and to which reference is made in this paper are fineness, permeability and bonding strength.

Method of Obtaining Samples

Some sixty samples were collected from the Albany district. Instead of taking these in person at the bank, the writer asked the firms of Whitehead Brothers Company, G. F. Pettinos, C. Pettinos, Albany Sand and Supply Company, and J. W. Paxson Company to supply him with samples of the different grades they produced. Special care was to be taken in the selection of the samples so that they could be considered as representative of the grades recognized by these producers. To all of these firms acknowledgments are due for the willingness with which they have responded.

With regard to the selection of the different grades at the bank, most foundrymen know that it is made by the "feel" method. Of this, however, more later.

Fineness or Sieve Test

Since the size and shape of the sand grains control to a large degree the physical properties of molding sands as well as the type of work to which they are fitted, it was thought best to consider the fineness test first and if possible to accurately group the sands into standard grades. With such a preliminary grouping the subsequent discussions on permeability and bonding strength will be on a more comparable basis.

The fineness test was carried out as recommended by the Sub-committee on Standard Tests and Table 1 gives the results of the sieve tests on these especially collected samples.

Method of Expressing Results

Before considering the sieve test figures in the above table, reference may be first made to the methods of illustrating and expressing these results.

It is quite obvious that, if we have a large table in which are given the percentages of sand retained on each sieve, one

may see with little difficulty that some samples run high and others low in fine and coarse grains. However, such a tabulation does not permit of quick and accurate comparison, and so to make such a series of real value some method of representation should be adopted.

Recognizing this need, attempts have been made in the past to formulate readily applied and easily understandable methods of expression, some of which are rather widely accepted at present. It would seem, however, that these methods are open to criticism and that a different method of visualizing sieve tests might perhaps lead to a wider application of them.

Average Fineness Figure

One of the common modes of expression is by the use of an average fineness figure, in which, by one of several methods a single figure is arrived at that is supposed to express the average size or per cent of fineness of the particles screened. The so-called Scranton method is the most popular and gives an average fineness figure by multiplying the weights of sand retained on each sieve by the mesh of the next larger sieve, taking the sum of the products and dividing by 100. Exactly 100 grams is used, any loss being credited to the middle sieve, and any that does not go through the 20 mesh sieve is credited to a 1 mesh sieve.

The following example will more clearly illustrate the method and calculations:

Weight of Sand Passing Through		Mesh of the Sieve		
55.22	×	100	=	5522.00
20.89	×	80	=	1671.20
11.64	×	60	=	698.40
10.57	×	40	=	422.80
1.20	×	20	=	24.00
.06	×	1	=	.06
.42	×	60	=	25.20
100.00				8363.66

Thus 8363.66 divided by 100 gives 83.6 as a percentage of fineness or average fineness figure.

Parmelee[1] has suggested taking the sum of the percentages passing each sieve, and dividing this by the number of sieves used. This gives a figure which may be called the per cent of

[1]N. J. Geol. Survey, Annual Report, 1904, p. 205.

fineness and serves as an approximate means of comparing sands with each other, provided each has been screened with the same series of sieves.

Ries and Rosen[2] assume an average size for each mesh, and this of necessity makes their method approximate rather than exact. However, since it is more accurate than the Scranton Method the following example is given:

Sieve Mesh	Weight Percentage Retained	Sieve Mesh Factor	
20	.0684	.066	.00451
40	.0661	.037	.00244
60	.4009	.019	.00762
80	.0898	.013	.00117
100	.2382	.011	.00262
250	.1256	.007	.00088
clay	.0106	.002	.00002
			.01926 average grain size

$$\frac{1}{.01926} = 51 \text{ average fineness}$$

In other words, if all the grains in a given volume of the sand, whose mechanical analysis is given above, were reduced to a uniform size, they would pass through a 51 mesh sieve.

Purdy[3] has suggested the use of a surface factor to express an average fineness figure. It is based on the assumption that the surface area of two powders, derived from a unit volume, are in inverse ratio to the average diameter of their grains, and hence the reciprocal of the average diameter is taken as the factor. Although the assumption is in error this factor affords an easy approximation and is sometimes used.

It is obvious that an average fineness or per cent of fineness figure obtained by any of these methods is not accurate because of the necessary assumptions which have to be made. Moreover, because it is an average, such a figure conceals and misinterprets just what it is supposed to make clear—the use to which the sand is best suited.

The main purpose in making sieve tests and separating sands into grades is to give some idea of the venting properties as well as the surface finish that would be left on a casting. For instance, a fine sand, such as a No. 1 Albany, is selected because a smooth finish is desired, which would be destroyed by

[2]Ries & Rosen, Mich. Geol. Survey, Annual Report, 1907, p. 50.
[3]Purdy, Trans. Amer. Ceram. Soc., Vol. 7, part 3, p. 441.

a relatively small percentage of grains on the 20 and 12 mesh sieves. An average fineness figure would totally hide the presence of such grains, especially if the sand should run a little low on the 270 mesh, and would thereby indicate a use for which the sand would not be fitted.

As an example of this three sieve analyses are given, the last one of which shows how greatly the percentages on the coarse screens may be increased by lowering the amount on the —270 mesh only one per cent. All three of these analyses have the same average fineness figure as determined by the Scranton method.

Mesh	No. 1	No. 2	No. 3
6	0.0	.10	1.10
12	0.0	1.00	5.03
20	0.02	9.70	9.70
40	.72	5.76	8.70
70	19.68	19.60	10.60
100	20.18	11.30	11.30
140	14.50	10.56	10.56
200	8.26	9.22	9.22
270	9.46	13.50	13.50
—270	11.40	11.00	12.01
Clay	16.70	9.14	9.14
Av. Fineness	98	98	98

On the other hand a coarse sand, such as a No. 4 Albany or a fine Milville gravel, is selected for large castings where easy venting is the important property and the surface finish is only secondary. The presence of a relatively small amount of fine silt will destroy this high permeability and of course an average fineness figure will usually conceal the presence of fine silt.

For these reasons an average fineness figure, when tried on a series of molding sand sieve tests, proves very disappointing. Perhaps a *weighted average fineness* figure might be used to better advantage. With such a method the percentages on the coarse screens for the fine sands, and those on the fine screens for the coarse sands, would be heavily penalized by some factor so that they would influence the final average fineness figure more than they do with the present methods.

Graphical Methods of Expression

Rectangular Co-ordinates

One of the usual methods of graphically showing a sieve test is to use rectangular co-ordinate paper, plotting the percent-

ages retained on each sieve as the ordinate or vertical component against the sieve sizes arranged along the abscissa or horizontal component. Sometimes the percentages are plotted as cumulative in which case the steepness of the resulting curve would give an idea of the character of the sand, a local flattening of the curve meaning a decrease in the percentage of sand on that sieve.

The main objection to using rectangular co-ordinates for visualizing a sieve test is in the plotting of the sieve mesh sizes. If these sieve sizes are equally spaced, as is the usual custom, all mathematical relation is destroyed because the difference in the size of the mesh opening between, for instance, the 6 and 12 mesh screen is more than fifty times greater than that between the 140 and 200 mesh. In fact the amount of increase in the size of opening for each successive sieve varies greatly and therefore it would be incorrect to equally space these sieve sizes when plotting them.

On the other hand if the sieve mesh openings are correctly plotted according to their real size, the coarse screens will take up all the room, leaving no place to adequately show the percentages of sand held by the finer screens. Since graphical representation should always be mathematically correct, this idea of using rectangular co-ordinates for the sieve sizes is considered to have doubtful value.

Logarithmic Co-ordinates

In trying to find a satisfactory method of more uniformly spreading the actual size of the sieve mesh openings, plotting on logarithmic paper was tried. This gave excellent results, especially if the rectangular co-ordinates were retained for the vertical plotting of the percentages of sand held by each sieve.

Therefore a combination was used, the actual percentage of sand on each sieve being shown on equally spaced rectangular co-ordinates, while the actual size of each sieve opening was plotted on logarithmic paper, or, which amounts to the same thing, the logarithms of the actual sizes of the mesh openings were plotted. By so doing, all of the plotting is correct mathematically and formulae can be derived from the plotted curves if it is so desired. See Plates 1 and 2.

Since using this method the writer has seen a paper by P. G. H. Boswell[4] who described a somewhat similar method of expressing sieve tests. He, however, used a cumulative manner of plotting the percentages of sand, instead of showing the actual percentage of sand on each sieve. It is thought that the method now suggested will give better graphical results for the "area curves" developed in this paper.

The actual size of the mesh openings shown on the graphs of Plates 1 and 2 was determined by the United States Bureau of Standards, with the exception of the "through 270," the figure for which is based on a number of measurements of the grains made with the microscope.

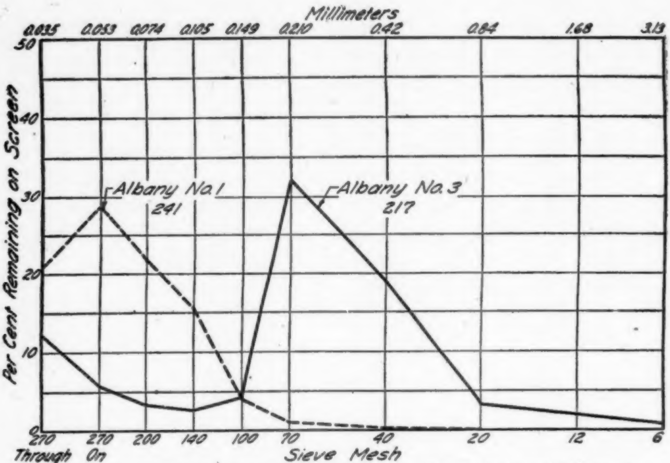
Standard Grades

It is with some hesitancy that this subject is approached as it is realized that, although the need of standard grades for molding sands is felt by both foundrymen and producers, many differences of opinion have made it a difficult matter to handle. However, because of the widespread use of Albany molding sands, it is perhaps not inappropriate that they should be used to illustrate the plan which the writer desires to suggest.

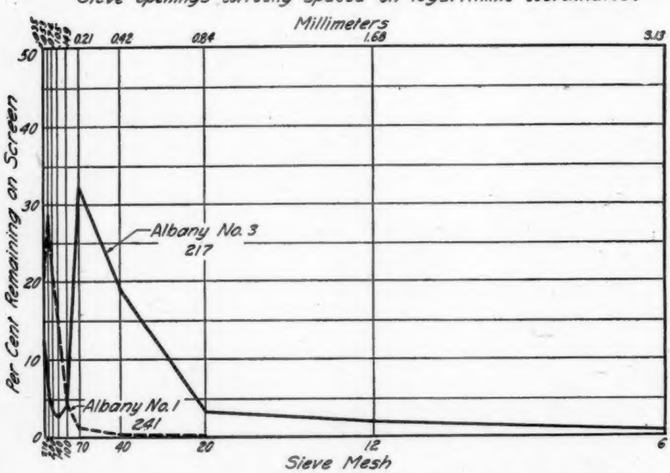
In the Albany district today there is some difference of opinion among the producers as to just how certain grades should feel to the fingers and thumb. Moreover certain producers recognize seven or eight grades in contrast to the three or four grades that were established by the pioneer producers. Therefore to be fair to all and yet to definitely outline the limits of a series of grades that will have a practical and wide-spread use, is something of a problem.

As already stated, all of the producers in the Hudson River district were requested to send in samples of what they considered to be their standard grades. These samples were carefully taken and represent the finger and thumb knowledge of men who have given a lifetime to molding sand production. After careful sieve tests the results were plotted as previously explained and characteristic curves for each grade soon began

[4]P. G. H. Boswell, *Memoir on British Resources of Refractory Sands for Furnace and Foundry Purposes.* Taylor and Francis, London, 1918.

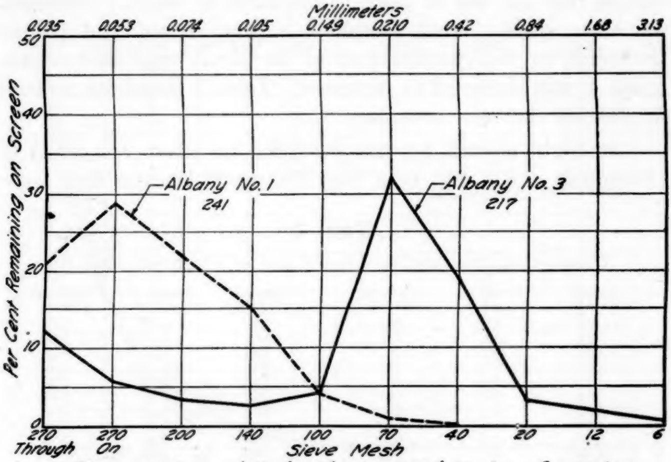


Sieve openings correctly spaced on logarithmic coördinates.

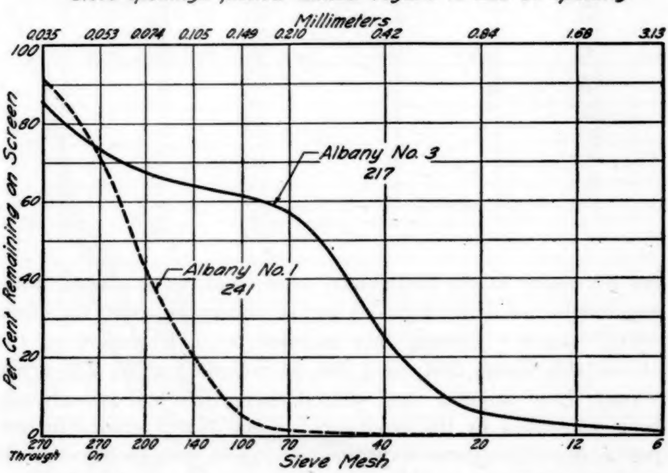


Sieve openings correctly spaced on rectangular coördinates.

PLATE 1



Sieve openings plotted without regard to size of opening



Cumulative percentages with sieve openings on logarithmic coördinates

PLATE 2

to take form. It was then a very easy matter to shift any sample that was out of place to the curve to which it belonged. In other words, every sample was sieve tested and plotted according to the characteristic of its curve, regardless of the grade it was supposed to represent. Table 2 shows the amount of shifting that was necessary.

It might be well to state here that no effort was made to distinguish a No. 2½ or a No. 3½ grade because they were

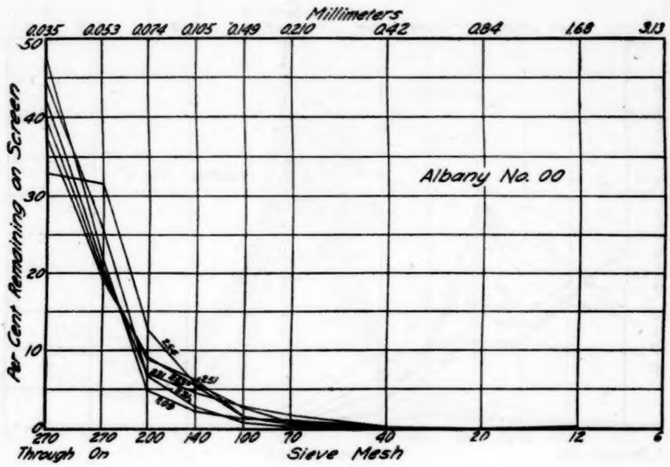
Table 2

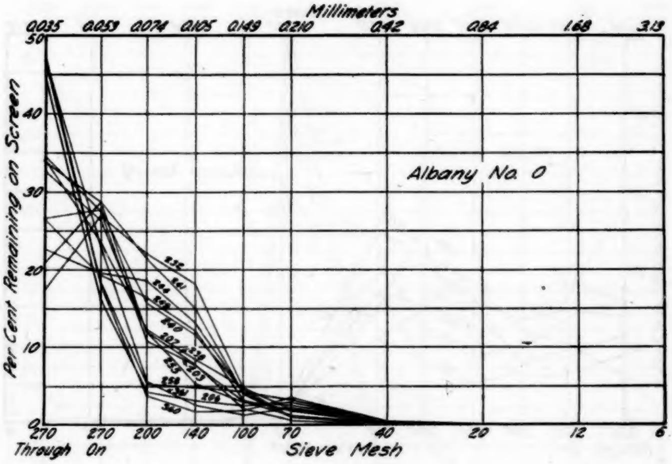
Comparison of Grades as Plotted and of Grades as Sent In

Sample Number	Grade as sent in	Grade as plotted	Sample Number	Grade as sent in	Grade as plotted
209	00	00	211	0	1½
221	00	00	213	1½	1½
231	00	00	246	1½	1½
251	0	00	256	2	1½
253	00	00	362	1	1½
254	00	00	365	2	1½
203	0	0	370	2	1½
206	1	0	371	3	1½
207	0	0	204	2½	2
232	00	0	205	3½	2
238	0	0	208	2	2
240	1	0	212	2	2
241	1	0	214	2½	2
244	0	0	216	2½	2
255	1	0	245	2	2
258	00	0	248	2½	2
360	000	0	257	3	2
361	00	0	261	2	2
215	1½	1	262	2½	2
228	1	1	263	3	2
239	1½	1	363	2	2
250	1	1	210	3	3
259	0	1	217	3½	3
260	1	1	218	3	3
364	1	1	219	3½	3
369	1	1	220	3	3
			247	3	3
			252	3½	3

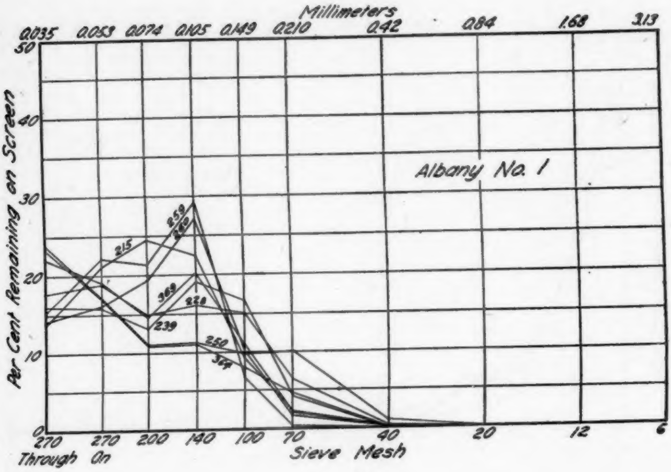
not necessary in the preliminary study and, as explained later, any number of desired grades can be chosen by using the "area curve" charts. Bearing this in mind, an examination of the above table shows that for a No. 2—including a No. 2½ grade—only three samples were placed there that had not already been so graded by the producers; in the No. 3 grade—including a No. 3½—there were no exceptions and in the No. 00 grade only one sample was out of agreement with the producers grading.

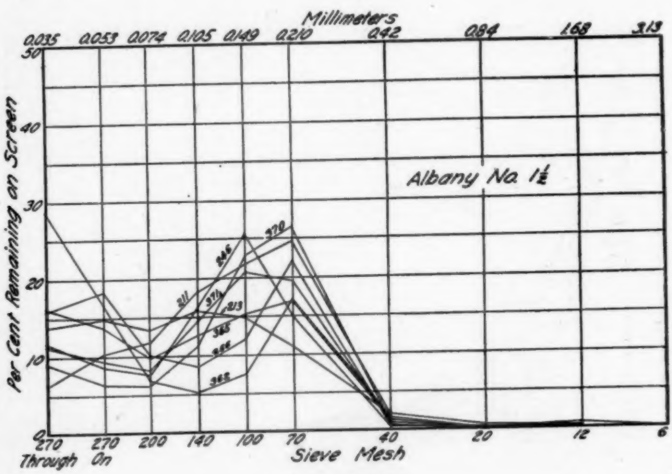
This also tends to bear out the writer's field observations, which are that the finer and the coarser sands seem to be


Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Per Cent Remaining on Screen
50
40
30
20
10
0
Albany No. 00
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh

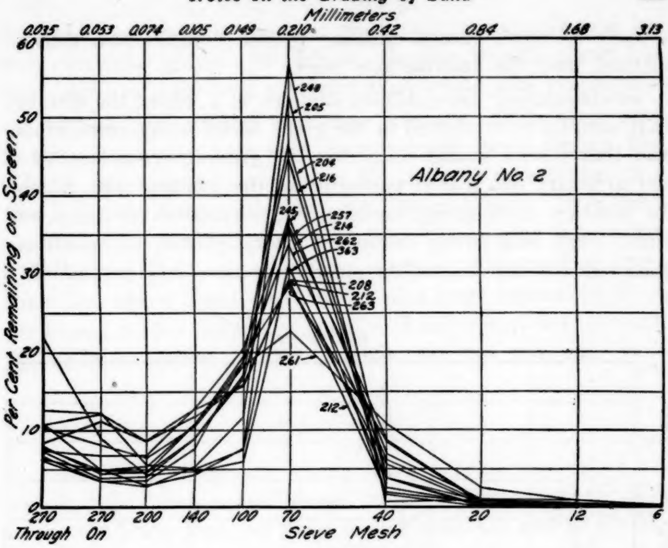

Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Per Cent Remaining on Screen
50
40
30
20
10
0
Albany No. 0
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh

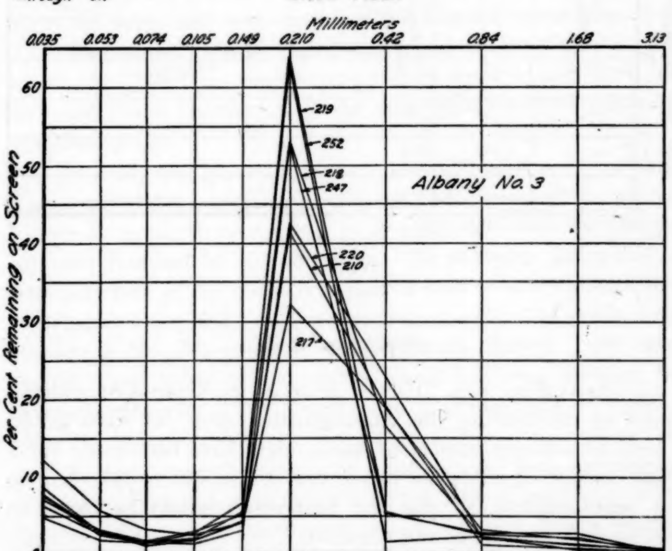
FIGS. 6 AND 7


Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Per Cent Remaining on Screen
Albany No. 1
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh


Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Per Cent Remaining on Screen
Albany No. 1½
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh

FIGS. 8 AND 9





FIGS. 10 AND 11

capable of more careful grading by the "fingers and thumb" method than the intermediate ones.

So considering these Albany samples as a whole, the distance that samples were shifted in the grade series is not considerable and therefore it would seem that the grading recommended is not arbitrary but that it conforms to the grading now in use. In addition each group contains representatives of open and tight, weak and strong sands, the characteristics of which are reserved for the discussion on cohesiveness and permeability.

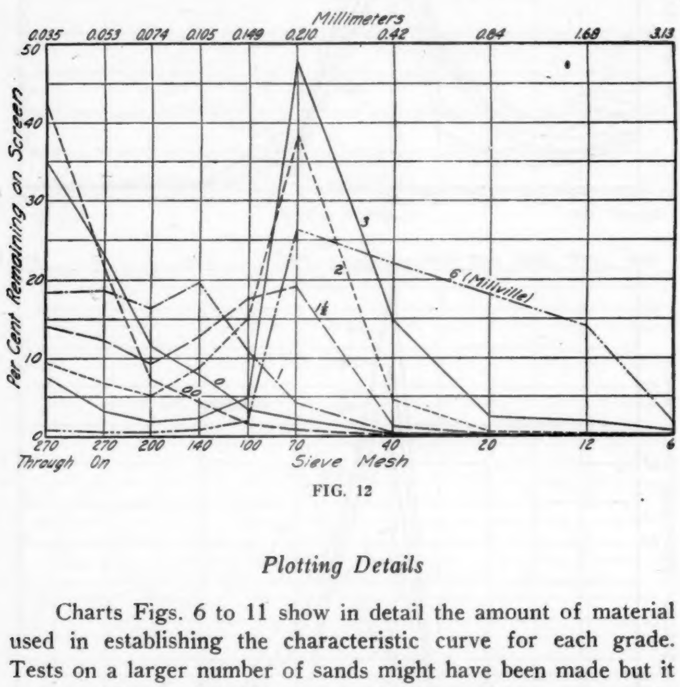


FIG. 12

Plotting Details

Charts Figs. 6 to 11 show in detail the amount of material used in establishing the characteristic curve for each grade. Tests on a larger number of sands might have been made but it was considered advisable to use only those which were sent in as representative, so that the final result would be based on actual field experience and selection.

On chart Fig. 12 the total plottings for each grade have

been averaged and the resultant plotted as the average type for each particular grade. In addition, the fine Milville gravel has been added to show how a coarser sand would look graphically.

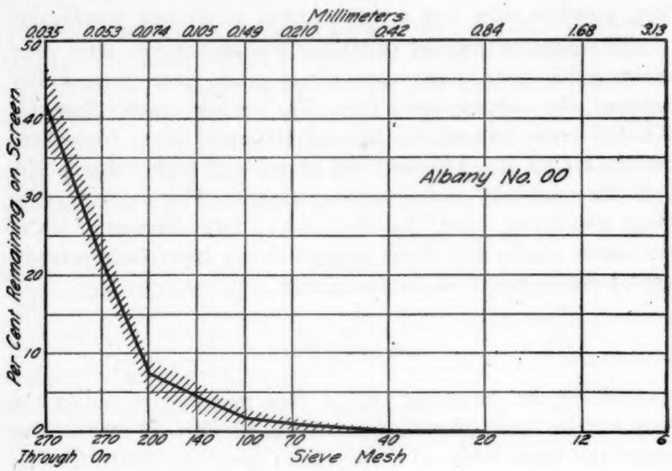
It should be noticed that these average curves after once crossing the curve of the next coarser grade, never recross. For instance, the average curve for a No. 1 grade crosses that of a No. 1½ grade between the 140 and 100 mesh sieve; from there on, the typical No. 1½ sand will always run higher than a No. 1, in the sand held on the coarser screens. This average curve chart also shows clearly the absence of a large amount of silt in the coarse grades and of the absence of any appreciable percentage of coarse grains in the fine grades.

Area Curves

All of the foregoing charts were prepared to obtain the data for the "area curves" shown in charts Figs. 13 to 15. The upper and lower limits of these shaded areas are plotted directly from the upper and lower limits of the detailed charts Figs. 6 to 11. The heavy average curve line is taken directly from the chart Fig. 12. Thus we have the typical trend of the curve for any one grade together with the suggested limits of tolerance for that grade.

In analyzing any sieve test to determine the grade of sand represented, it is important to take the entire trend of the plotted curve, so as not to be mislead by peculiarities in the percentage of sand retained by any one sieve. By studying this trend or characteristic of the curve it is just as easy to select a sand that represents a No. 2½ grade as one that is a No. 1½ grade, even though a No. 2½ grade is not separately shown. Any sand, which, upon being plotted, comes about half way between the average curve for a No. 2 and a No. 3 grade could be called a No. 2½ grade.

In fact a complete series of grades exists, each overlapping the other, from the very finest imported French sand to a coarse gravel. Thus, since the shaded areas of adjacent grades overlap, with this method of graphical interpretation any number of


Millimeters
0.035 0.053 0.074 0.105 0.149 0.210 0.42 0.84 1.68 3.13
50 40 30 20 10 0
Per Cent Remaining on Screen
Albany No. 00
270 Through 270 On 200 140 100 70 40 20 12 6
Sieve Mesh

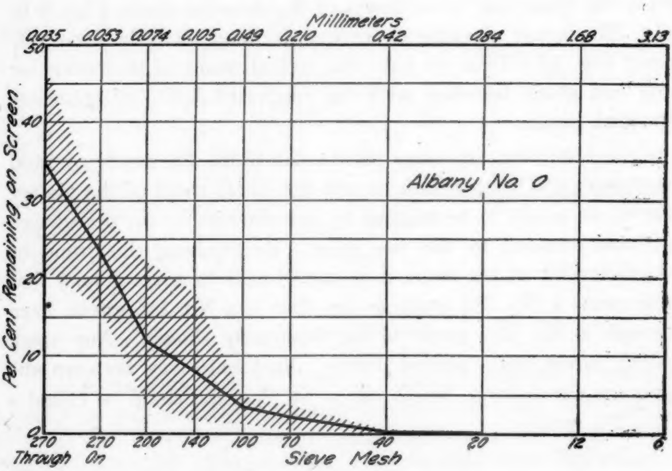
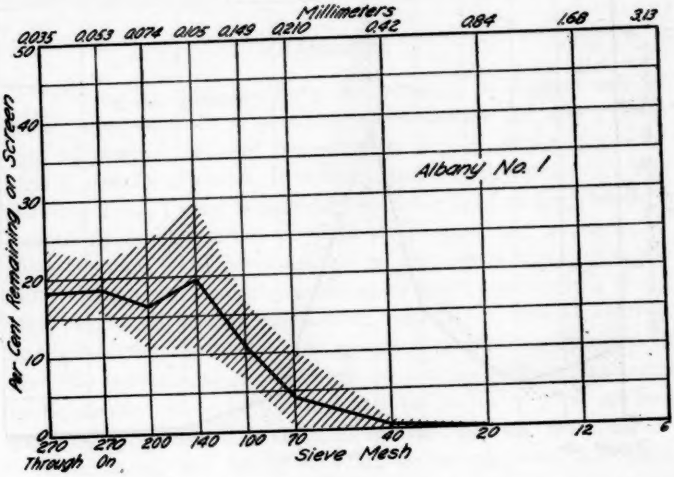

Millimeters
0.035 0.053 0.074 0.105 0.149 0.210 0.42 0.84 1.68 3.13
50 40 30 20 10 0
Per Cent Remaining on Screen
Albany No. 0
270 Through 270 On 200 140 100 70 40 20 12 6
Sieve Mesh

FIG. 13


Millimeters
0.035 0.053 0.074 0.105 0.149 0.210 0.42 0.84 1.68 3.13
Per Cent Remaining on Screen
50
40
30
20
10
0
Albany No. 1
270 Through
270 On
200 140 100 70 40 20 12 6
Sieve Mesh

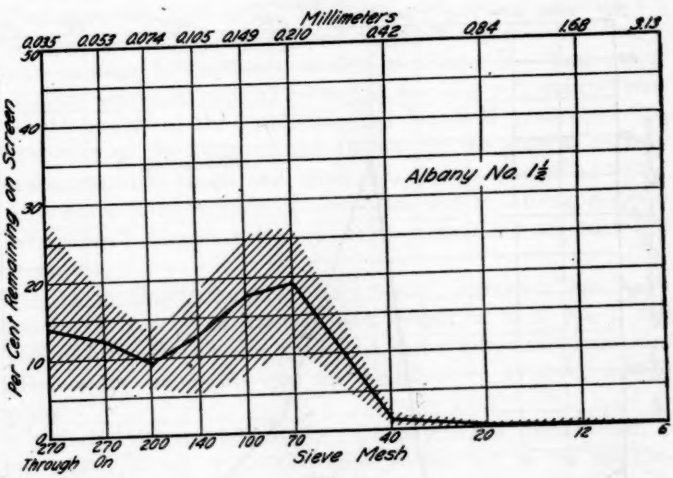
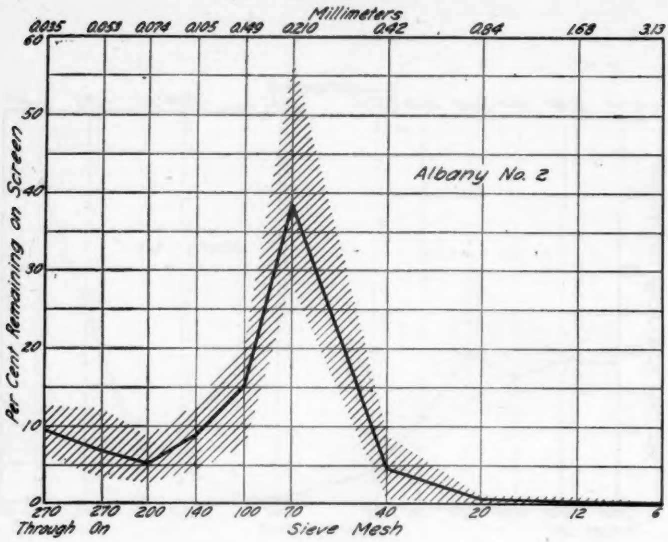

Millimeters
0.035 0.053 0.074 0.105 0.149 0.210 0.42 0.84 1.68 3.13
Per Cent Remaining on Screen
50
40
30
20
10
0
Albany No. 1½
270 Through
270 On
200 140 100 70 40 20 12 6
Sieve Mesh

FIG. 14


Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Albany No. 2
Per Cent Remaining on Screen
60
50
40
30
20
10
0
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh

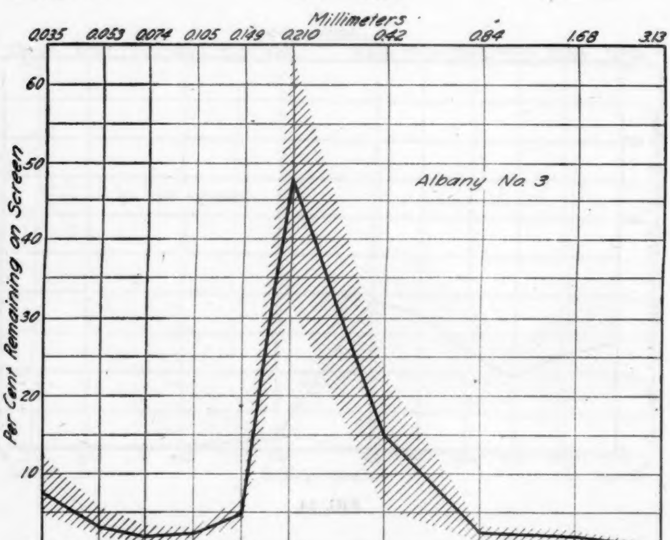

Millimeters
0.035
0.053
0.074
0.105
0.149
0.210
0.42
0.84
1.68
3.13
Albany No. 3
Per Cent Remaining on Screen
60
50
40
30
20
10
0
270 Through
270 On
200
140
100
70
40
20
12
6
Sieve Mesh

FIG. 15

grades and sub-divisions are possible, although it is thought the suggested grades are sufficient for a standard of comparison.

Application

The writer does not have the temerity to suggest any of these "area curves" as standard specifications for any certain type of casting, because the selection of the proper grade of sand is usually a matter of training and foundry practice. For instance, a No. 1 sand is generally used for light castings where a smooth finish is desired, yet this same sand may be used for large castings if properly opened up with vent wires. On the other hand, some foundries make quite small castings in a No. 2 sand because it is quite permeable, requires no special venting, and will stand the abuse that quantity production entails. In fact, the tendency seems to be to use coarser and coarser sands to be assured of easy venting and to obtain a good surface finish by applying a special facing mixture.

So, although the fine grades are commonly used for brass, aluminum and light gray iron work, the medium grades for radiator and bath-tub work, and the coarse grades for heavy, large castings, it would seem useless to connect any "area curve" with any particular type of casting except in a very general way.

However, in the establishing of standard grades for the education of the "fingers and thumb" in the control of field operations, it is hoped that these area curves may be of value. Also in the interpretation of sieve tests and in settling disputes over refused shipments, the area curve method is both quick and accurate.

As an illustration a certain foundry ordered a No. 0 Albany. On receipt of same it was judged to be a No. 2 and placed in the bin for that grade. A sieve test of this sand supplied to the writer fits into the No. 2 curve as given in this paper.

One additional advantage, especially to the foundrymen, in the standardizing of molding sand grades, will be the straightening out of the differences in grading between districts. In Kentucky the fine sands are graded as No. 6 and the coarse sands as No. 0, which is just the reverse of the usual practice.

Many neighboring districts, while not approaching this extreme, still show quite an appreciable difference in their grading. Is there any logical reason for continuing a No. 6 grade when it does the same work and falls into the same grade as a No. 1 Albany? Perhaps it is time that a uniformity of grading between districts is established so that all sands may be described in the same language.

Permeability

Having referred to the grading of the Albany sands according to their fineness, we should consider next their permeability and see what relation it bears to the fineness grades. Table 3, on page 211, gives the permeabilities of the Albany samples, the tests being conducted according to the Standard Permeability Test devised by the American Foundrymen's Association.

The samples are arranged in grades as determined previously by the area curves. Columns 5 and 6 give the maximum permeability and the corresponding moisture content, while columns 3 and 4 and 7 and 8 give the permeability on either side of the maximum peak, with the amounts of water used in tempering. In the case of samples No. 206 and No. 263 the maximum permeability persists over a wider range of moisture than the others, and a plotted curve for the permeability would be very flat.

Upon studying this permeability table it is clearly evident that there is a peak for each sand, where with the optimum or "best" water content at from five to thirteen per cent the maximum permeability is developed. This wide variation in the optimum water would have been expectable if the above table had represented a series of tests on sands from many different districts. However, when it is remembered that these Albany sands all have the same origin and approximate character of bonding material, it is rather surprising.

Of course the amount of bonding material varies with the different samples and the natural explanation would be that the more bond that is present, the more water would be required to temper it. That this explanation is probably the true one, rather than that the character of the bonding material is different, is shown by the fact that all of the sands with low optimum

Table 3

Table Showing Permeability with Varying Per Cents of Water and Also Maximum Permeability

Sample Number	Grade as plotted	Per cent water	Permeability	Per cent water	MAXIMUM PERM.	Per cent water	Permeability
209	00	8.0	5.8	9.6	10.7	11.5	7.5
221	00	6.0	6.3	8.7	7.5	10.7	6.5
231	00	5.5	6.4	7.4	7.3	10.5	5.8
251	00	7.5	6.3	9.5	7.2	11.8	6.5
253	00	9.6	4.9	12.2	7.2	13.9	6.0
254	00	9.7	10.0	11.7	13.0	13.6	8.2
203	0	8.0	10.3	9.4	11.8	11.9	7.9
206	0	9.7	8.5	11.3	9.7	13.8	9.7
207	0	6.1	10.1	8.6	11.7	9.6	10.7
232	0	6.0	21.0	8.0	22.0	9.5	21.8
238	0	6.0	7.2	8.0	9.5	10.0	7.5
240	0	3.8	12.2	5.8	17.3	8.0	15.7
241	0	4.0	21.0	5.6	22.0	7.9	18.4
244	0	6.0	10.0	8.3	13.4	12.1	10.0
249	0	6.0	8.2	8.0	9.4	12.0	8.8
255	0	8.7	10.7	10.4	13.0	12.3	10.7
258	0	4.0	4.7	6.0	7.7	8.0	7.5
360	0	10.2	7.7	11.9	8.8	14.3	6.0
361	0	7.8	8.2	10.5	9.0	13.2	7.2
215	1	3.4	21.0	5.6	24.0	7.9	23.0
228	1	6.0	18.3	8.0	18.5	10.0	15.2
239	1	6.1	16.7	8.0	19.0	9.8	17.3
250	1	11.6	7.0	13.1	10.0	15.4	7.5
259	1	4.0	15.7	6.0	18.4	8.0	18.4
260	1	6.0	21.0	8.3	22.7	9.9	20.0
364	1	8.0	14.7	10.0	15.7	12.7	10.7
369	1	6.0	14.7	8.0	20.0	10.0	15.7
211	1½	5.8	44.0	7.6	44.5	9.6	42.0
213	1½	8.0	21.2	9.6	25.8	11.7	12.2
246	1½	10.0	18.2	11.4	19.0	14.0	11.8
256	1½	6.0	18.4	8.0	21.0	10.1	16.7
362	1½	7.5	10.7	10.0	13.8	13.1	5.1
365	1½	6.0	16.2	8.0	23.4	10.3	19.0
370	1½	6.0	29.0	8.3	52.0	10.5	31.0
371	1½	6.0	24.2	8.3	44.0	10.2	34.0
204	2	5.0	75.0	7.0	81.0	9.7	67.0
205	2	7.2	54.0	9.4	80.0	10.8	42.0
208	2	3.6	23.3	6.0	29.0	....	....
212	2	6.0	27.6	8.2	34.0	9.5	31.0
214	2	3.0	41.0	5.0	68.0	8.0	49.5
216	2	5.8	60.0	7.5	70.0	9.5	56.0
245	2	8.0	27.0	10.0	44.0	11.8	36.0
248	2	3.4	63.0	5.8	112.0	8.0	105.0
257	2	6.0	30.0	8.0	44.0	10.1	18.4
261	2	7.6	38.0	9.9	44.0	11.9	17.8
262	2	6.0	44.0	8.0	52.0	10.0	44.0
263	2	6.0	42.0	7.5	49.0	10.0	49.0
363	2	6.1	14.7	7.7	19.0	10.0	17.8
210	3	6.0	68.0	8.0	169.0	10.1	133.0
217	3	5.8	16.4	8.1	50.0	9.5	36.0
218	3	5.8	135.0	7.8	190.0	9.2	176.0
219	3	6.0	185.0	7.4	358.0	9.4	167.0
220	3	5.7	105.0	8.2	143.0	9.4	138.0
247	3	8.0	93.0	10.0	96.0	11.7	47.0
252	3	5.0	55.0	7.0	173.0	9.3	162.0

water give a low break in the cohesiveness test, and those with a high optimum water for the maximum permeability are strongly bonded.

It is of interest to notice that some sands show a very sharp

break at the peak with greatly diminished permeability for either more or less water than the optimum. In other sands a difference of four or five per cent of water does not greatly affect the permeability. This is of practical importance to the foundryman as a sand with a flat peak will stand more leeway in the tempering control and cause fewer faulty castings. For instance, sample No. 263 with a water variation of four per cent shows only a slight change in permeability, in contrast to sample No. 257 which shows a very sharp drop off in permeability from the maximum with a very slight change in the tempering water.

Coming now to the relation of permeability to the fineness or grade of a sand it might be well to point out that this relation is influenced by the shape, size and arrangement of the sand grains. Since all of the Albany sands are sub-angular in grain outline, the effect of the shape is not very important in this instance. The size of the sand grains, however, directly affects the permeability as it is obvious that appreciable percentages of fine silt will clog up the pore spaces and hinder the passage of gases.

This is well illustrated by the following examples which are out of alignment with the usual permeabilities of their grade, and which would be considered very close, tight sands for that respective grade. That this permeability is due to fine silt is evident. In fact, in the final averaging of the permeability for each grade these three samples were disregarded.

Sample No.	Grade	Maximum Perm'ty	Av. Perm. for that grade	Perct. —270	Av. Perct. —270 for that grade
362	1½	13.8	30	28.7	12.0
363	2	19.0	60	21.7	9.4
217	3	50.0	200	12.1	7.0

So it has been the usual practice to connect low permeability for any grade with the presence of a large amount of clay and fine silt. As far as the presence of the clay bond is concerned, this idea is not correct, since, with proper tempering, the bond will uniformly coat the sand grains and not clog up the pore spaces. An example of this may be seen in the Millville gravels which are often strongly bonded but which give a permeability of 800 to 1,000.

Indeed it is sometimes unfair to attribute low permeabilities to the presence of fine silt as in each group there are samples with higher permeabilities than similar ones in the same group which have even less clay and fine silt. Table 4 groups the samples by twos for comparison and in each case it is seen that the sample with the larger amount of clay and silt—minus 270—has the higher permeability.

Table 4

Sample Number	Grade	Maximum Perm'ty	Perct. Clay	Thru 270
209	00	10.7	21.1	47.7
231	00	7.3	18.4	44.7
369	1	20.0	9.7	22.0
259	1	18.4	4.5	15.3
371	1½	44.0	16.7	11.4
246	1½	19.0	13.9	11.7
205	2	80.0	15.1	10.8
212	2	34.0	9.3	8.4
252	3	173.0	12.7	8.7
220	3	143.0	11.3	7.1

In the above samples the arrangement of the sand grains and the percentage of each size are more influential than the amount of silt present. Whenever then there is sufficient diversity of grain size so that there are enough particles of any one size to fill the interstices between those of the next larger size, the sand will have a lowered permeability and a smoother, more regular fineness curve.

Grading of Permeability

The range of permeabilities for molding sand is very wide, starting with about five for the finest sands and increasing to over one thousand for some of the Millville gravels. It has been the usual custom to speak of high, low and medium permeabilities by roughly dividing this entire range of from 5 to over 1,000, without considering the fineness grade of the sand. Yet in actual practice the grade of the sand and the permeability are closely linked together. Foundrymen usually change their order to a coarser grade simply to get increased permeability. Moreover in placing an order, say for a No. 2 molding sand, an open sand is often specified since, for each grade of sand, there exist high and low permeabilities.

Therefore since permeability is so intimately associated with the fineness grading of molding sands, both from a prac-

tical as well as from a theoretical viewpoint, it is considered advisable always to think of permeability in terms of the grades.

With this in mind Table 5 was prepared from Table No. 3 to show the usual permeabilities for each grade of Albany molding sand. It is realized that there will be considerable overlapping of values as for instance an open No. 1½ sand might have a higher permeability than a close No. 2, but even so this overlapping will not be harmful and will merely tend to show the sand in its true relation.

Table 5

Grade Number	Low Perm'ty	Medium Perm'ty	High Perm'ty
00	5	8	13
0	7	13	20
1	10	18	25
1½	20	30	50
2	30	60	100
3	100	200	300

By inserting a No. 2½ grade, which can be very easily done from the area curves, the large jump between the No. 2 and No. 3 grades would be remedied. In fact this method of grading permeabilities is just as elastic as the "area curve" method with which it goes hand in hand. Thus a permeability of 13 would be considered high for a No. 00, typical for a No. 0, and low for a No. 1. A permeability of 13 by itself without the grade being given would have little meaning.

This method of grading permeabilities is offered merely as a suggestion as it is realized that in order to have this widely accepted it will be necessary to study sands from other districts. Even with tentative limits such as suggested above it is hoped that the permeability figure will mean more and have a wider use among foundrymen and producers.

Cohesiveness or Bonding Strength

The bonding strength of the Albany molding sands was determined in accordance with the standard methods recommended by the Joint Molding Sand Research Committee. Table 6 gives the bonding strength for the different sands as grouped according to the area curve method.

Table 6

Table Showing Cohesiveness With Varying Per Cents of Water and Also Maximum Cohesiveness

Sample Number	Grade as plotted	Per cent water	Cohesiveness	Per cent water	MAXIMUM COHES.	Per cent water	Cohesiveness	Per cent clay	Per cent through 270
209	00	4.0	182	6.0	203	8.0	200	21.1	47.7
221	00	6.0	171	8.7	186	10.7	174	20.1	42.3
231	00	5.5	168	7.4	176	10.5	169	18.4	44.7
251	00	6.0	174	7.5	188	9.5	187	24.1	39.6
253	00	5.0	185	7.4	200	9.6	199	27.0	37.3
254	00	4.0	171	6.0	186	8.0	181	13.1	33.0
203	0	4.0	196*	6.0	190	8.0	182	14.7	34.6
206	0	3.7	185	6.2	199	8.3	199	18.9	44.7
207	0	3.9	142*	6.1	181	8.6	172	12.8	34.1
232	0	4.0	*	6.0	133	8.0	123	9.2	17.2
238	0	6.0	171	8.0	184	10.0	175	18.2	32.7
240	0	5.8	151	8.0	153	9.7	145	12.3	26.6
241	0	9.6	133	11.9	142	13.2	132	7.8	20.8
244	0	4.4	*	6.0	175	8.3	163	19.3	22.7
249	0	6.0	172	8.0	172	12.0	169	19.5	26.5
255	0	4.0	147	6.0	251	8.7	227	13.5	33.9
258	0	4.0	188	6.0	190	8.0	187	16.0	46.7
360	0	6.3	171	7.8	187	10.2	185	22.1	47.4
361	0	7.8	171	10.5	179	13.2	176	17.1	46.8
215	1	5.6	130	7.9	139	9.8	126	6.5	13.5
228	1	6.0	*	8.0	140	10.0	137	10.1	17.7
239	1	6.1	*	8.0	159	9.8	156	14.2	16.0
250	1	11.6	186	13.1	202	15.4	190	24.0	24.0
259	1	4.0	*	6.0	145	8.0	138	4.5	15.3
260	1	4.3	140	6.0	173	8.3	149	10.2	14.1
364	1	3.9	180	5.8	206	8.0	172	15.8	23.5
369	1	4.3	*	6.0	178	8.0	161	9.7	22.0
211	1½	3.8	115	5.8	119	7.6	118	5.4	6.1
213	1½	3.8	161	5.6	159	8.0	149	12.3	13.9
246	1½	8.0	160	10.0	161	11.4	151	13.9	11.7
256	1½	2.0	*	4.0	208	6.0	174	10.9	15.9
362	1½	3.7	*	6.1	196	7.5	182	14.7	28.7
365	1½	4.2	167	6.0	200	8.0	168	13.2	16.1
370	1½	4.1	*	6.0	241	8.3	195	16.7	9.1
371	1½	4.1	197	6.0	247	8.3	188	16.7	11.4
204	2	3.0	*	5.0	120	7.0	102	8.7	6.1
205	2	3.0	149	5.0	181	7.2	156	15.1	10.8
208	2	2.0	*	3.6	148	6.0	135	7.7	10.8
212	2	3.4	140*	6.0	158	8.2	145	9.3	8.4
214	2	5.0	119	8.0	121	8.6	110	6.9	7.4
216	2	2.0	*	3.6	151	5.8	141	9.9	6.3
245	2	4.7	*	6.3	169	8.0	154	12.1	7.3
248	2	3.4	*	5.8	126	8.0	98	10.1	6.5
261	2	3.0	117	4.0	157	5.6	144	9.8	10.3
257	2	4.0	138	6.0	150	8.0	123	10.6	12.6
262	2	3.0	104	4.0	158	6.0	147	11.4	7.7
263	2	2.0	*	4.0	161	6.0	137	14.2	7.9
363	2	3.0	*	3.9	179	6.1	177	13.8	21.7
210	3	4.0	146	6.0	173	8.0	127	15.8	7.6
217	3	3.9	157	5.8	204	8.1	167	14.5	12.1
218	3	3.4	*	5.8	132	7.8	97	10.6	6.3
219	3	2.0	*	4.0	106	6.0	103	9.2	4.8
220	3	4.3	123*	5.7	131	8.2	102	11.3	7.1
247	3	4.0	*	6.0	157	8.0	148	14.5	7.6
252	3	3.0	*	5.0	158	7.0	129	12.7	8.7

*Too dry.

Columns 5 and 6 give the maximum bonding strength and corresponding moisture content, while columns 3 and 4 and columns 7 and 8 give the bonding strength with corresponding moisture contents, on either side of the peak.

These results of the cohesiveness test indicate a peak or maximum strength for each sample with one certain water percentage of tempering. This optimum or "best" water of tempering for cohesiveness oftentimes does not coincide with that of the maximum permeability, although the same physical forces are doubtless in control in both cases. This matter is taken up in some detail in another paper on "The Relation of Water to Permeability and Bonding Strength of Molding Sands."

In this connection it might be well to point out here that over half of the Albany sands develop their best strength with about 6.0 per cent of water, which should be contrasted with the usual 7.5 to 8.5 per cent of water for their best permeability. This gives the foundryman some option in tempering his Albany sand so as to bring out that property which he most desires.

Because of the nature of the test, the cohesiveness figures are not as accurate as those determined for the permeabilities. For this reason the peaks of the curves for the maximum cohesiveness are inclined to be flat and should be depended on only in a general way. With many sands from other districts, where the character of the bonding material is different, this maximum cohesiveness is developed more sharply and a loss of strength results with a very slight change in tempering. With most Albany sands, however, a change of two or three per cent in the amount of water does not seem to make much difference in the strength, as long as the sand is not under-tempered.

Comparing the Albany sands as a whole with molding sands in general, the lower average strength of the bond is an outstanding characteristic. Strong molding sands have a cohesiveness figure of 300 to 400 which is in decided contrast to 200 to 250 for the stronger Albany sands. A typical Albany sand will average between 150 and 200 grams cohesiveness which is about a medium-bonded sand.

It would seem at first thought, that so weak a sand would not resist the cutting action of molten metal or would not faith-

fully reproduce intricate molding shapes. Yet Albany sands are noted for good performance in these respects. It has been claimed by some investigators that the reason for this lies in the sub-angular character of the Albany sand grains, since this type withstands cutting action and transmits molding pressure easily. In fact a sub-angular grain tends to inter-lock and form a good face with a surprisingly small amount of bonding material.

As to this amount of bonding material it is thought that the figures given for the percentage of "clay substance" are not as significant as they might be since they contain unknown amounts of fine silt and inert material that are not true colloids and have no bonding action. It might be well to further separate this "clay substance" by elutriation when making a sieve test, or the dye test might help to give a better idea of the true character of this bond.

Grading of Cohesiveness

Even with the "clay substance" percentages in their present unsatisfactory form it is evident that the grading or fineness of the sand enters into the real bonding strength of the sand only in a minor way. The real controlling force is the character and amount of the bonding material. That is we can expect to find just as strong sands in the coarse grades as in the finer grades, if there is sufficient bonding material present to coat all the sand grains. It is true that we find more strong fine sands than strong coarse sands, partially because the fine sands present a larger surface area, but practically the grade of the sand does not make a whole lot of difference.

A glance at the cohesiveness Table No. 6 for Albany sands would seem to confirm this. In addition 200 molding sands from many different states and districts, representing all grades from a very coarse gravel to the finest sand, show this same disregard of the effect of grain size. Therefore it is suggested that the grading of the bonding strength should not be connected in any way with the fineness grading but should be expressed separately.

In the following table there is suggested a terminology that might be used to express bonding strength, as well as the

strength ranges to which each might apply. The third column gives the percentage of about 200 samples of all grades, which occur in each group.

Table 7

Nomenclature	Tentative Limits of Strength	Usual Perct. of Occurrence
Extra weak	below 80	0.0
Very weak	80—100	1.5
Weak	100—150	17.2
Medium	150—200	33.0
Medium strong	200—250	21.4
Strong	250—300	13.1
Very strong	300—400	12.5
Extra strong	400—500	1.3

As should be expected over 50 per cent of the molding sands fall into the medium to medium-strong group. Those below 80 are usually too weak and require the addition of a binder, while those above 400 are usually too strong and have to be opened up to vent satisfactorily.

Summary

It has been shown that a series of sieve tests may be expressed graphically to good advantage and that the different samples of any one grade conform more or less closely to an average curve for that grade. In fact tentative tolerance limits have been suggested for each grade in the form of area curves.

Since we can do this for Albany sands, the question naturally arises as to whether other sands cannot also be included in such a scheme of grading. Thus for example if sands conforming to the area curve of a No. 1 Albany are found in Ohio and Kentucky, why not call them all a No. 1 with respect to the grade, instead of calling one a No. 5, a second a No. 1, and a third a No. BB.

In this connection it should be remembered that the permeability may be linked with such a grading but that the bonding strength should be expressed separately.

With the successful standardizing of the testing methods it is felt that the time has come to begin sizing up and correlating our molding sands. By so doing, the discovery of new deposits and the successful blending of molding sands, will be made much easier. Even the drawing up of sand specifications

for certain types of foundry work, which may seem at present to be a long way off, is only a question of applying correct grading methods and the right amount of tolerance.

If the following suggestions serve to arouse interest and discussion in this grading of molding sands, even though they are later proven to be inadequate, their purpose will have been fulfilled.

In conclusion the writer wishes to thank Dr. H. Ries for his many helpful suggestions in the preparation of this paper.

Investigations of the Molding Sand Resources of Illinois

By M. M. LEIGHTON,* Urbana, Illinois,

At the suggestion of the American Foundrymen's Association, the Illinois Geological Survey undertook in 1923 an investigation of the molding sand resources of Illinois. This decision was reached only after some standardized tests, which would permit of comparisons with testing results of sands made by other State surveys, had been formulated by the Joint Committee on Molding Sand Research, organized by the American Foundrymen's Association and National Research Council.

Eighty-five counties of the one hundred and two counties of the State were studied, those omitted being counties from which there has been no production reported and whose geological conditions indicate that they are barren territory. A total of 139 samples was collected and tested, 57 from producing pits, 42 from new deposits, and 40 from foundries. All the known producing pits were visited. Twenty-nine new deposits of commercial promise were found and sampled. As a result of this study a conservative estimate of the State's molding sand resources places them at approximately 9,000,000 tons.

In order that the study should be conducted as nearly as possible from the viewpoint of the foundryman, the field men visited 40 foundries in Chicago, Peoria, East Moline, Rock Island, East St. Louis, Quincy, and other cities to study foundry practice, to obtain information regarding their molding sand problems, to obtain data on sand production in Illinois and importation from other states, and to collect samples of sands which had been found to be satisfactory from the standpoint of actual foundry practice with the view to testing these and using the results for checking the results of "unknown" sands. The 40 samples collected from foundries included 24 Illinois sands and 16 "foreign" sands.

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*Chief, Illinois Geological Survey.

The testing of all the sands was done co-operatively by the Engineering Experiment Station of the University of Illinois and the Illinois Geological Survey, in the Foundry Laboratory of the Department of Mechanical Engineering. The work was done by Max Littlefield, a graduate student in geology at the University of Iowa, who also carried out the field study and sampling, and his assistant, R. S. Datta, a senior student in engineering at the University of Illinois. In addition to the standardized tests, base permeability tests (with the clay removed) were made on all the sands, and durability tests (percentage of bond strength lost by heating for two hours at a temperature of 600 degrees Fahr.) on 48 sands.

The hearty co-operation of the University of Illinois Engineering Experiment Station and the valuable supervision of B. W. Benedict, manager of the shop laboratory, and R. E. Kennedy, superintendent of the foundry laboratory, are gratefully acknowledged.

EDITOR'S NOTE.—The Illinois Geological Survey and the University of Illinois Engineering Experiment Station have kindly consented to having the test data obtained by their organizations incorporated in the report of Molding Sand Tests issued by the A. F. A. as a report of the Joint Molding Sand Research Committee. The report of the Illinois Sand Resources will be found on page 361 of this volume.

Report of Chairman of Joint Committee on Molding Sand Research

To the Members of the American Foundrymen's Association:

The work of the Joint Committee on Molding Sand Research has been successfully carried on and considerable progress made during the past year. This report will serve to call to your attention the general advance made since the last convention. The Chairman of the Sub-committees on Tests Geological Surveys, and Conservation and Reclamation will present detailed reports of the work done by them.

Soon after the Cleveland convention, R. A. Bull, Chairman of the Joint Committee on Molding Sand Research, found it necessary to discontinue active participation in the work of the Committee, and later tendered his resignation to the Board of Directors of the American Foundrymen's Association. The foundry industry owes much to Major Bull for his keen foresight and good judgment in conducting the work in molding sand research. As a member of the Board of Directors of the American Foundrymen's Association, he was appointed chairman of the joint committee when it was organized to investigate molding sands. The results of his untiring efforts have been seen in reports made on molding sand at the Cleveland convention, and the influence of his work is felt at the present time.

The personnel of the joint committee has suffered but few changes during the past year, although several additions have been made. Early in the year various local foundrymen's associations were invited to name a representative to the Joint Committee on Molding Sand Research. The reply to this invitation was unanimous. This addition helped to strengthen the joint committee by disseminating knowledge of the work throughout a wider field of foundry interests.

The total membership of the Joint Committee on Molding Sand Research now numbers sixty persons, about one-half of whom are actively engaged in work on sub-committees. The remaining number have given valuable assistance in an advisory capacity. The joint committee, representing as it does the foundry interests, together with a number of sand producers, engineers, metallurgists, and geologists, is exceptionally constituted to conduct the investigation for which it was organized.

The work accomplished during the past year consisted in revising and improving the methods of testing molding sand, completing the testing of samples of sand collected under the direction of the Sub-committee on Geological Surveys, and further investigations on conservation and reclamation of molding sands.

At the Cleveland convention of the American Foundrymen's association, May 1, 1923, the Joint Committee on Molding Sand Research announced the tentative adoption for one year of three methods of molding sand tests; the fineness, bond or cohesiveness, and permeability, two supplementary methods, a chemical analysis and dye adsorption, and a method for sampling molding sand. It was the earnest desire of the joint committee that these six methods and tests be put in daily employment in the numerous foundries of the country, and as a result information obtained as to whether they would be satisfactory in practical use.

As the result of the practical application of these methods, the Sub-committee on Tests decided to recommend changes in the cohesiveness and permeability tests. The permeability apparatus was found to be costly to construct and liable to breakage, and the need of a portable apparatus become apparent. After considerable study by the sub-committee, a simplified permeability test was developed, having the same principles and accuracy as the original apparatus, but more flexible for daily use.

The bonding or cohesiveness test was changed so that it expressed the bonding strength in terms of actual weight in grams of the breaking strength of the bar, including the mois-

ture, instead of in percentage as in the method previously used. The fineness test remains as adopted except for a change in dimensions and tolerances of the sieves made necessary by a revision of sieve sizes by the United States Bureau of Standards.

The six above mentioned methods of testing with the changes recommended have been tentatively adopted by the Executive Committee of the Joint Committee on Molding Sand Research, and published by the American Foundrymen's association June 1, 1924, as "Tentatively Adopted Methods of Tests and Resume of Activities of the Joint Committee on Molding Sand Research." Additional corrections were announced in the August, 1924, bulletin of the American Foundrymen's association.

The Sub-committee on Geological Surveys, with the assistance of some of the state geologists, has continued the collection and testing of sands which are suitable for foundry purposes, found in various states. The work of testing under the direction of this committee has been carried on at sand testing stations, maintained by the Joint Committee on Molding Sand Research, at the U. S. Bureau of Standards and Cornell University. Two research assistants have been employed for nearly a year at each station, and have made tests on a large number of sands according to the standard methods recommended by the Joint Committee on Molding Sand Research. The work at these stations has now been completed and the employment of the assistants discontinued.

The members of the various sub-committees have given valuable services and time without compensation. The work conducted by the committees, however, involves certain expenses, such as the salary of research assistants, travelling, stationery, and clerical assistance. As the committee has no source of income, it becomes necessary to meet these expenses from money contributed by those interested, and those who will ultimately benefit by the results of the research.

Due to the progress made since the reorganization of the Joint Committee on Molding Sand Research, and the results accomplished, it appears that the general foundry interests will

be greatly benefited by the research. Therefore, it seems possible that it will be to the advantage of the members of the American Foundrymen's association to continue the interest which they have manifested in the work.

Respectfully submitted,

WALTER M. SAUNDERS, *Chairman*,
Joint Committee on Molding
Sand Research.

Report of Sub-Committee on Testing Methods

To the Members of the American Foundrymen's Association:

At the Cleveland convention of the A. F. A. held in April, 1923, the first report of the Sub-Committee on Testing Methods was presented by Mr. H. B. Hanley, chairman, under whose efficient guidance the work had been carried on. Stress of other work has unfortunately prevented his retaining this position, which he resigned in April, 1924, so that the time covered by this report was largely included in his term of office.

In the previous report you were advised that six tests had been carefully studied by the committee, and methods for conducting these recommended. These tests were tentatively adopted for one year, and have been described in a pamphlet issued by the A. F. A. in June, 1924.

During this year of probation, as it were, it was hoped that different foundries or laboratories using the methods recommended by the committee might make constructive suggestions, leading to the betterment of the method or apparatus, and the members of the sub-committee also had the same ideas in mind.

It may therefore be proper to state first whether any criticisms of the methods recommended have been received, or whether any changes are considered desirable by the sub-committee on testing methods.

Fineness Test:—No major criticisms regarding the method of making this test have been received, so that the general method of procedure remains the same.

Attention should be called to the fact that the Bureau of Standards has adopted a revised set of standard specifications for sieves, which permit a considerably large tolerance for wire diameter and average openings than heretofore specified. These revisions have been accepted by the Joint Committee on Molding Sand Research, and have been printed in the special bulletin above referred to.

The suggestion has also been made that distilled water

should be used in connection with the fineness test, because of its freedom from electrolytes, but since its use would in many cases entail considerable extra trouble, the sub-committee is not prepared to recommend its use without further experimental evidence of its importance and necessity.

A further suggestion has been the possible desirability of making a separation of the particles now included in the clay substance, but no definite recommendation is made on this.

Bonding or Cohesiveness Test:—This test has been in use at a number of foundry laboratories, and has also been further considered by the sub-committee at its meetings. No changes are recommended in the apparatus used, but the suggestion has been made by several persons that a mechanical release for the weight would be desirable.

Several changes in the method have, however, been recommended by the sub-committee and approved by the Executive Committee.

The first of these refers to paragraph 11, page 31.* The sub-committee recommends now that a sufficient quantity of tempered sand (approximately 1,000 grams) be taken to make a bar one inch thick, with a tolerance of not more than 3 per cent.

The second revision refers to the method of determining the average of the bars. The original wording in paragraph 19, page 35, read to average the results of the "average breaks from each bar" and that "the bars should yield averages which do not vary more than 5 per cent from each other."

As this does not seem clear to everyone the committee has recommended rewording the last two sentences so as to read: "If properly carried out, the test of the number of bars as specified should yield an average from which no individual bar should vary by more than 5 per cent. Failure to meet this requirement indicates faulty manipulation."

An important change recommended is the method of expressing the bonding strength. So instead of the method given in paragraph 20, page 36, the following is substituted:

"The bonding strength is to be expressed in terms of the actual weight in grams of the average breaking strength including moisture." This is a simpler form of expression.

******Tentatively Adopted Methods of Tests and Resume of Activities of Joint Committee on Molding Sand Research,* **American Foundrymen's Association, June 1, 1924.**

These corrections have been already distributed by the Secretary in the form of gummed slips, which can be fastened into the pamphlet.

Permeability Test:—Of all the tests previously reported on, this one has perhaps required more thought by the sub-committee than any other.

The method as recommended by the Sub-Committee on Testing Methods at the Cleveland convention seemed correct in principle, and still appears so, but there was a feeling than an effort should be made to not only simplify the apparatus, but also make it as unbreakable as possible.

You will remember that the apparatus presented to you at Cleveland was constructed largely of glass and occupied considerable space. It was, however, quite accurate, although not very rapid in its action.

In order to more effectively attack the problem of a more convenient apparatus. a sub-committee of the sub-committee on tests was appointed with instructions to concentrate its energies on the improvement if possible of the permeability apparatus and method of making the test.

The smaller committee held several meetings, burned considerable midnight oil, and carried on much correspondence. Different types of apparatus were built and tested, the final result being that an apparatus has been recommended which for making standard tests operates on the same principle as the Bureau of Standards apparatus formerly recommended. It has, however- the advantages of: (1) Being so compact as to be easily portable, so that it can be taken into the foundry and used anywhere. (2) Having no glass parts except the manometer tube, (3) Cheaper cost of manufacture, (4) Greater lightness, (5) Adaptability to rapid work, (6) Possibility of operating with a direct reading scale from which the permeability can be read directly, and (7) It requires no constant supply of water, or tap connection.

This apparatus was completed in time to insert a description of it in the special pamphlet on testing methods issued in June, 1924, and need not be described again here. Since then

the Secretary has distributed a supplementary instruction dealing with the selection of the orifices to be used for rapid work.

Dye-Absorption. Chemical Analysis and Sampling:—No criticisms have been received regarding these methods as previously recommended by the Sub-Committee.

Compression Test:—While the bond test as recommended by the committee is already being used in a number of foundries, some have criticized it as being insufficiently delicate, and have suggested a compression test of the tempered sand as being more satisfactory. Indeed the compression test is now in use at some foundries. The Sub-Committee on Testing Methods has given some consideration to this test, and is collecting data regarding its use, preparatory to proceeding with the formulation of a proposed standard apparatus and method for making the test.

Refractoriness and Life Tests:—It would seem that there may be some confusion regarding these two terms. By refractoriness may be understood the temperature at which a sand fuses. By life, we may refer to the ease with which a sand burns out and loses its bonding qualities, a change that may occur at a much lower temperature than its fusibility.

No standardized test has yet been recommended for determining either of the above qualities.

The sub-committee, feeling that both are desirable and even necessary, has them under consideration.

For the refractoriness test a series of sands, representing considerable variety, is to be distributed to three laboratories, which will co-operate with the committee.

Two of these, the Bureau of Mines station at Columbus, and the Bureau of Mines at Ottawa have already been selected.

Large samples of the sand, taken from the same lot will be distributed to each of the co-operating laboratories, where there will be conducted a series of refractoriness tests carried out under a variety of conditions. The several laboratories will serve as a check on each other, and from the results obtained from them the committee hopes to be able to prepare recommendations for a standard method of making the test. This work will

include a consideration of both the fusion and vitrifying points of the sand.

The sub-committee has also under consideration the formulation of a method for determining the life of a sand, but is awaiting the results of co-operative tests now being carried on at the laboratories of the Ohio Brass Company, U. S. Radiator Corporation, and Hunt Spiller Company, before coming to a final decision in the matter. These experiments include heating the sand up to 600 degrees Fahr., and noting the deterioration that takes place.

In conclusion it may be said that the Sub-Committee on Testing Methods recognizes that it should get results as soon as possible, but all conclusions which it comes to, must only be arrived at, after the most careful consideration.

As was pointed out by the preceding chairman, it does not aim to restrict its activities to attempts to originate new methods. It can consider testing methods now in use, and by further investigation show that they are capable of improvement and use as standards for determining certain properties of sands, or on the other hand, it may find that other apparently promising methods or apparatus do not yield the results that were hoped for, or are applicable only to certain types of sand.

The successful use of the few methods already worked out, or improved by the sub-committee leads to the belief that when the importance of these standard methods of testing is more widely recognized, foundrymen the country over will feel the need of their aid.

Respectfully submitted,

H. Ries, *Chairman.*

Discussion—Report of Subcommittee on Sand Test Methods

T. R. Scott: It seems that there have been a number of concerns using this apparatus to make tests of sands in the foundries, and I would be very much interested to hear what sort of result they got from putting in the apparatus and trying it out to blend their sands

or prepare their sands differently from what we old-fashioned fellows know about.

CHAIRMAN W. M. SAUNDERS: These tests have been put to daily use in several foundries. I think there are one or two papers that will follow, either at this session or the following session, that will describe the results of those tests.

P. T. BANCROFT: We have an installation of a sand slinger molding machine, whereby we are using our sand from twelve to fourteen times a day. As this machine throws your sand and rams it uniformly, it means that we have to keep our bond and moisture quite uniform to get the proper product. We have been conducting tests daily for about one year, and in that time I can say that we have gotten it down to a point where we have determined which percentage of moisture and what point of bond or cohesiveness gives us the best grade of castings. We have increased our percentage of good castings very materially in that time. That has been our result in testing the sand in our foundry. We have had no trouble with any of the apparatus so far. The permeability test I am using is the castright instrument, which gives me a comparison; it is not a standard. The cohesiveness test is the standard recommendation by our sand research committee.

R. F. HARRINGTON: While I have a paper to present later, I might give you some idea of the amount of work that is being done by this apparatus. We are running forty to fifty determinations a day on control work in the shop, in addition to the research work that we are doing, in an endeavor to improve our molding sand conditions. We have great faith in it and believe that there are big things ahead for those who will go into sand testing as recommended by the A. F. A. Committee.

Report of Sub-Committee on Geological Surveys

To the members of the American Foundrymen's Association:

As stated in the report of this sub-committee presented at the Cleveland convention, in April, 1923, its function is to stimulate an investigation of the sand resources of the different states.

It has also seemed that the proper medium through which this work should be handled, is the geological survey or mining bureau of each state, whichever form of organization exists.

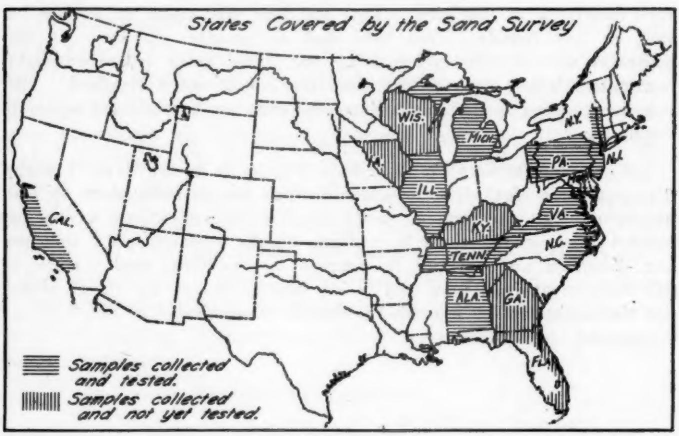

FIG. 1—MAP SHOWING EXTENT OF SURVEYS AND TESTING WORK OF COMMITTEE

Starting out therefore with this plan, the different state organizations were approached by correspondence, and this was later followed up by more letters, and several conferences with the state geologists at several of the annual meetings of their association.

A year ago we were able to report that a number of state geologists had agreed to undertake the field investigation of their molding sand resources, and we are now able to further

report that most of them have kept their promise, and still others have become interested in the idea. Insufficient appropriations have retarded or prevented the work in some states, while in some others we must still convince them of our earnestness of purpose, and the importance of the task which we wish them to undertake.

The accompanying map (Fig. 1) shows the present status of the work.

From this it will be seen that the states of Virginia, Tennessee, Michigan, Alabama, New Jersey, Pennsylvania, North Carolina, and Illinois have collected samples from all parts of the state, and these have all been tested, according to the A. F. A. recommendations.[1]

The states of California, Maryland and New York have collected samples from a limited area, and there is no certainty, unfortunately, of any further work in them. Kentucky, Wisconsin and Iowa have collected samples this summer, and they will be tested during the coming winter. Two important states, Ohio and Indiana, still remain blank. Minnesota has issued an independent report containing a number of sand tests, but these were not made in accordance with A. F. A. standards and hence are not comparable with the results of tests made on the sands from other states.

During the field seasons of 1922 and 1923 there were collected a total of 728 samples. Of these, 255 samples were sent to the testing station at the Bureau of Standards, Washington, D. C., and 334 were sent to the testing laboratory in the Department of Geology, at Cornell University, Ithaca, N. Y., the work at these two stations being supported by the A. F. A.

Of the above total, 139 samples were collected by and at the expense of the Illinois Geological Survey and tested by the Engineering Experiment Station of the University of Illinois at its expense. These two organizations have, however, kindly placed the results of these tests at the disposal of the American Foundrymen's Association, so that they can be included with the tests made at the A. F. A. testing stations.

[1]*Tentatively adopted Methods of Tests of The Joint Committee on Molding Sand Research*, American Foundrymen's Association, June 1, 1924.

Copies of all these tests are now submitted to the American Foundrymen's Association, and in accordance with the agreement made with the state geological surveys, duplicate copies are being forwarded to them, each state geologist receiving the tests of the sands collected in his state.

The tabulated tests, together with a brief discussion of them, are presented as an appendix to this report.

Table 1

Summary of Sands Tested

State	Total Samples	Where Tested: Cornell University	Bureau of Standards	Univ. of Ill.
Alabama	90	22	68	
California	12		12	
Illinois	139			139
Maryland	6		6	
Michigan	150	90	60	
New Jersey	36	36		
New York	58	58		
North Carolina	42	3	39	
Pennsylvania	20	20		
Tennessee	72	2	70	
Virginia	103			
Grand Total	728	334	255	139

Sands to Be Tested 1925

Pennsylvania	26	Michigan	12
Kentucky	25	Florida	12
Tennessee	2	Georgia	50
New Jersey	6		
Wisconsin	101		234

Now as to future work in the United States, if the A. F. A. desires it, the Sub-committee on Geological Surveys will continue its efforts without relaxation until the country is covered.

If the state geologist of any state is not able to or is not interested enough to carry on the work, it can perhaps be accomplished through some other agency.

Only recently, the board of commerce in a certain city, located in a state where the state survey has not undertaken a sand survey, we are told raised $50,000 for investigating the mineral resources of the territory tributary to that city. We have been informed that there is a good chance of some of this appropriation being devoted to molding sand work.

Our Canadian friends have not yet begun any sand survey work, but we feel encouraged to hope that they will start it soon.

In conclusion the chairman of your sub-committee ventures to suggest that there is a fine opportunity for some of the A. F. A. members to use their influence on the proper authorities in those states where our interests have thus far been neglected.

Respectfully submitted,

H. Ries, *Chairman*

Report on Sand Tests Conducted Under the Auspices of the American Foundrymen's Association

PART I—DESCRIPTION OF TESTS

The tables given in this report contain the results of tests made on 589 samples of sand collected by the different state geological surveys, and tested at the two stations supported by the American Foundrymen's Association, located, respectively, at the Bureau of Standards, Washington, D. C., and at the Department of Geology, Cornell University, Ithaca, N. Y.

The sand tested at the Bureau of Standards were as follows: All from North Carolina, except Nos. 45a, 46a, and 319; all from Tennessee, except Nos. C-2 and C-5; all from California and Maryland; Alabama samples Nos. 1 to 68, inclusive, and all Michigan Nos. between 512 and 517 and 2046 and 3018, inclusive. Those tested at Cornell were Tennessee Nos. C-2 and C-5; North Carolina Nos. 45a, 46a, and 319; Alabama Nos. 469 to 490, inclusive; Michigan Nos. 236 and 700 to 787, inclusive, and all from New York, New Jersey, Pennsylvania and Virginia.

Following the table of tests from each state, there are given under the respective laboratory numbers, such data as have been supplied regarding the occurrence, geology and uses of the sand. In all cases where the sample was obtained from an unworked deposit no statement regarding its use is made in the column of table headed uses or grade, but in the case of worked deposits its use is given, whenever this has been supplied to us.

All of the samples which were tested have been run for fineness, bonding strength, and permeability in accordance with the standard methods recommended by the A. F. A. In addition samples of all the sands collected at Washington and Ithaca were sent to the laboratory of Saunders & Franklin, at Providence, R. I., who very kindly had dye adsorption tests made on all of them.

In making the permeability and bonding strength tests, the sands were mixed up with different percentages of water, in order to determine the peak of the curves for these two properties. Theoretically the successive moisture contents should differ by two per cent, and this was adhered to as closely as possible, although it is often difficult to hit the desired water percentage exactly. For economy of time, and since the optimum water content of many sands is around 6 per cent, it was found easier to mix the sand up with this amount of water first, and work either way from it. In some cases this meant mixing up not more than three samples to get the peak. In other cases the sand had to be mixed up with successively higher or lower water percentages until it was either too wet or too dry to work.

With such a mass of data as are contained in these tables and the compilation of which was not entirely completed until shortly before the meeting, at which they were presented, there has not been sufficient time to digest all the figures presented.

It stands to reason, however, that they represent a variety of sands.

One especially interesting point to which attention may be called is the relation between the permeability and bonding strength. If we plot curves showing these two properties between the points where the sand is too dry and too wet to work, we get a somewhat interesting series as shown in Fig. 1.

Looking at the upper pair of curves in the three columns, we notice three types as follows:

1. The peaks of bond and permeability curves agree.
2. The bond strength peak is at a higher water content.
3. The permeability peak requires the higher amount of water.

It is probable that many of the freakish looking curves in columns 2 and 3 are really similar to the top curves, and were we able to test them very wet or dry, a peak would develop in each case. Assuming then that this might be the case, they have been classified as shown in the figure.

These graphs have been figured from about 200 sand samples, and include both molding and core sands. At the bottom of each of the columns, represented in Fig. 1, there are

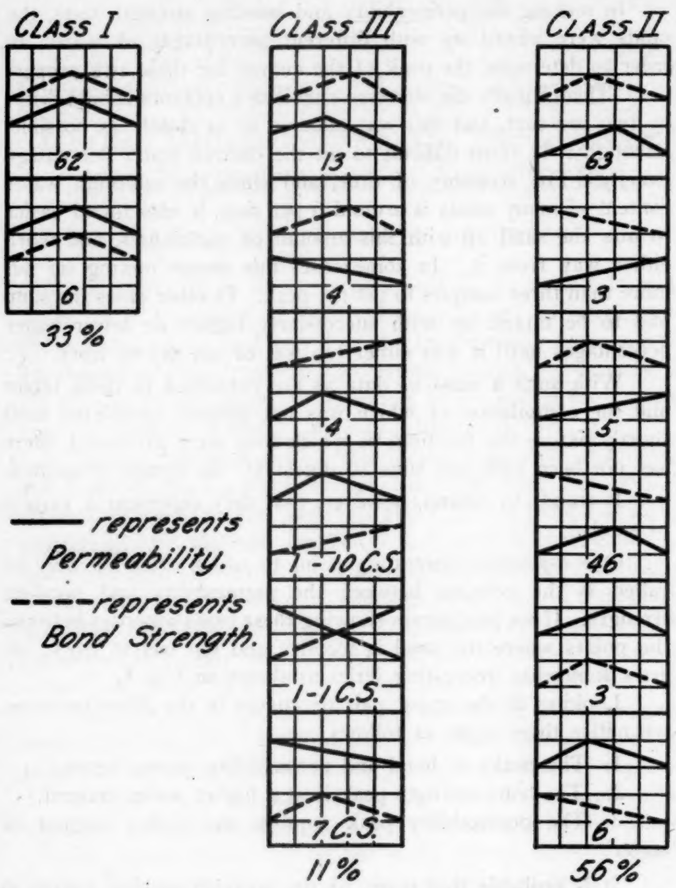

FIG. 1—CURVES SHOWING RELATION BETWEEN PERMEABILITY AND BONDING STRENGTH OF THREE TYPES OF SANDS

given the percentage of molding sands (excluding core sands) which fall in each group.

Considering those cases where the bonding strength was determined with different water contents, it will be noticed that

even a sand with a very low percentage of clay substance may give a bar strong enough to test.

The charts given in Figs. 2 to 7 may be taken as representative of some of the variations noted. In each case the

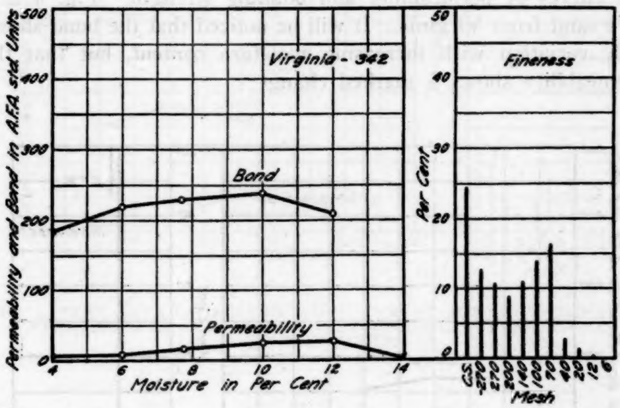

FIG. 2—TEST DATA OF SAND SHOWING FLAT CURVES OF BOND AND PERMEABILITY

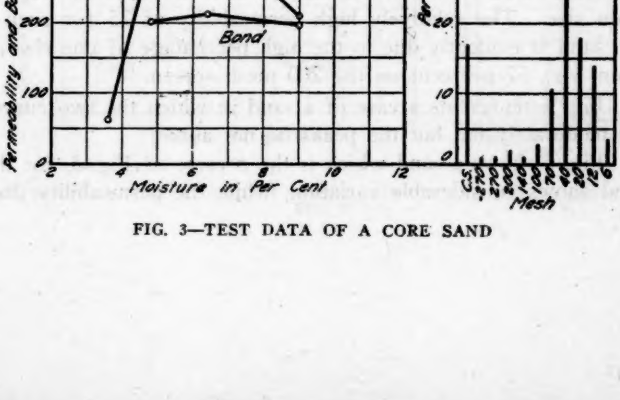

FIG. 3—TEST DATA OF A CORE SAND

bonding strength (B) and permeability curves (P) are given. In the upper left hand corner of each chart we have a diagrammatic representation of the texture, showing the percentage of the different sized grains. Fig. 1 is a flood plain sand from Buena Vista, Va., used for iron casting, which exhibits rather flat curves of permeability and bonding strength. Fig. 4 is a core sand from Virginia. It will be noticed that the bond shows little variation with increasing moisture content, but that the permeability shows a marked change.

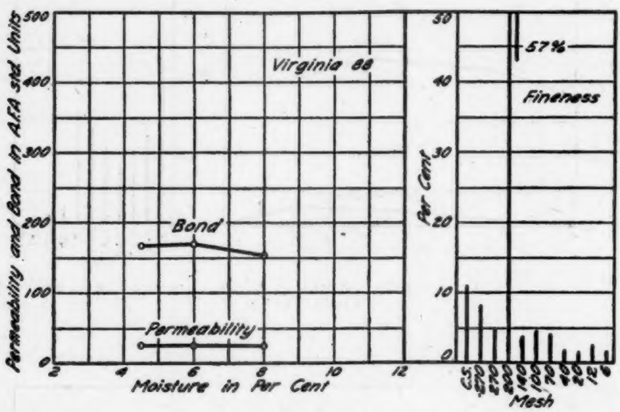

FIG. 4—TEST DATA SHOWING VERY FLAT CURVES FOR BOTH BOND AND PERMEABILITY

Fig. 4 is a sand from southeast of Fredericksburg, Va., which shows a very flat curve for both permeability and bonding strength. Nearly three-fifths of the sand is made up of one grain size. The relatively high permeability of 25 for such a fine sand is evidently due to the high percentage of one size of grain, viz., 57 per cent on the 200 mesh screen.

Fig. 5 represents a case of a sand in which the two curves are moderately flat but the peaks do not agree.

Fig. 6 shows a sand which is the reverse of Fig. 3, for the bond shows considerable variation, while the permeability does not.

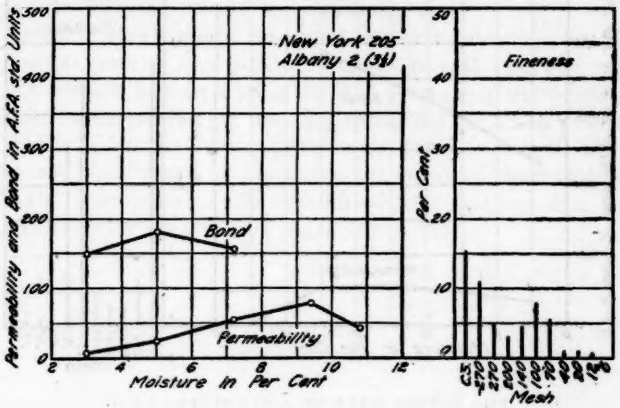

FIG. 5—TEST DATA OF A SAND WHEN CURVES FOR BOTH BOND AND PERMEABILITY ARE RATHER FLAT BUT WHEN PEAK POINTS DO NOT AGREE

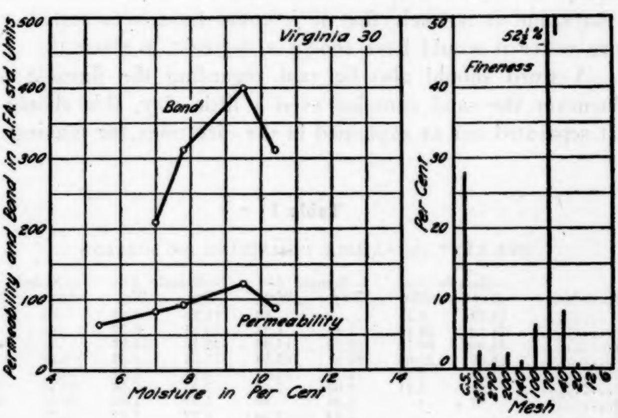

FIG. 6—TEST DATA ON A SAND WHERE CURVES ARE THE REVERSE OF FIG. 3

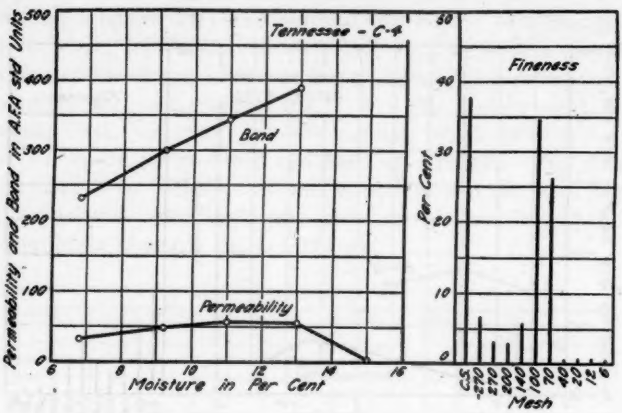

FIG. 7—TEST DATA OF A TENNESSEE SAND

Fig. *7* is a Tennessee sand that is in actual use. It will be noted that the permeability shows little variation between 11 and 13 per cent of moisture, but that the bonding strength rises steadily to 13 per cent. The sand then becomes too wet to test in bars, but it is likely that if it could have been tested with more water it would have shown a decrease in strength.

A word should also be said regarding the fineness test. Whenever the sand contains even a little clay, this should be first separated out as explained in the directions for making the

Table 1

PER CENT OF SAMPLE REMAINING ON SCREENS

Sieve No.	Sample 1 Dry	Sample 1 Wet	Sample 2 Dry	Sample 2 Wet	Sample 3 Dry	Sample 3 Wet	Sample 4 Dry	Sample 4 Wet
12	10.78	3.30	.....	.68	11.26	4.03	.03	.....
20	14.10	24.10	1.31	1.94	13.31	5.78	.06	.....
40	44.40	44.10	22.52	15.88	30.12	14.88	.92	.09
70	28.60	26.68	50.91	43.54	21.01	14.28	6.09	.72
100	1.36	1.02	11.10	11.58	4.01	2.88	16.37	9.00
140	.31	0.21	3.03	5.44	2.43	1.56	46.23	39.16
200	.07	.....	1.20	.80	1.77	1.44	26.01	36.26
270	.....	.....	5.14	3.34	1.74	1.92	1.77	.54
Through 270	.05	.....	4.52	.88	12.73	14.50	2.51	2.12
Clay substance	.....	0.49	.....	14.71	.....	40.35	.....	11.56
Total	99.67	99.90	99.73	98.79	98.38	101.62	99.99	99.45

test. If such a sand is sifted dry without first separating the clay, quite different results are obtained.

Table 1, which brings this point out quite clearly, contains the fineness tests of four different sands. In each case one was run dry without first separating the clay by shaking and settling, and then by its elimination previous to sieving the stand grains.

The complete test data of the sands tested at Cornell University and the Bureau of Standards are given on pages 244 to 358. The description of the methods of tests and test data of the Illinois sands are given on pages 359 to 391.

Report on Sand Tests Conducted Under the Auspices of the American Foundrymen's Association

PART II—GEOLOGICAL SURVEY DATA

Alabama

Lab. No.: 1.
Location: Gadsden, east bank Coosa River.
Producer: Huff & Sons.
Formation: Heavy molding sand.
Grade: Alluvial deposits.

Lab. No.: 2.
Location: Gadsden, east bank Coosa River.
Producer: Huff & Sons.
Formation: Alluvial deposits.
Grade: Light molding sand.

Lab. No.: 3.
Location: One-half mile N. E. of bridge at Gadsden.
Producer: J. W. Godfrey.
Formation: Alluvial sand, river and creek bottom.
Grade: Molding sand.

Lab. No.: 4.
Location: One and one-half miles S. of Gadsden.
Producer: Joe Moragne.
Formation: Coosa River Valley alluvial sand.
Grade: Molding sand.

Lab. No.: 5.
Location: One and one-half miles S. of Gadsden.
Producer: Joe Moragne.
Formation: Coosa River Valley alluvial sand.
Grade: Molding sand.

Lab. No.: 6.
Location: Four miles S. of Attalla.
Producer: C. B. Forman.
Formation: Alluvial origin.
Grade: Light molding sand.

Lab. No.: 7.
Location: Attalla.
Producer: C. B. Forman.
Formation: Colluvial origin, red loam.
Grade: Molding sand.

Lab. No.: 8.
Location: One-fourth mile N. of Reads Mill station.
Producer: E. N. Reads.
Formation: Creek alluvium.
Grade: Molding sand.

Lab. No.: 9.
Location: One and one-fourth miles W. of Wellington Station.
Producer: J. W. Mills.
Formation: Alluvium sand.
Grade: Coarse molding sand.

Lab. No.: 10.
Location: One mile W. of Wellington Station.
Grade: Fine molding sand.

Lab. No.: 11.
Location: One mile S. of Wellington Station.
Producer: J. H. Priebe.
Formation: Alluvial deposit.
Grade: Molding sand.

Lab. No.: 12.
Location: Benjamin Station.
Producer: Wolf Creek Sand Co.
Formation: Alluvial deposit.
Grade: Pipe core sand.

Lab. No.: 13.
Location: Benjamin Station.
Producer: Wolf Creek Sand Co.
Formation: Alluvial deposit.
Grade: Heavy molding sand.

Lab. No.: 14.
Location: Benjamin Station.
Producer: Wolf Creek Sand Co.
Formation: Colluvial origin, red loam.
Grade: Molding sand.

Lab. No.: 15.
Location: Benjamin Station.
Producer: Wolf Creek Sand Co.
Formation: Alluvial deposit.
Grade: Pipe sand.

Lab. No.: 16.
Location: Coosa river bottom at Riverside.
Producer: W. J. Stines.
Formation: Alluvial deposit.
Grade: Pipe shop sand.

Lab. No.: 17.
Location: Coosa river bottom at Riverside.
Producer: W. J. Stines.
Formation: Alluvial deposit.
Grade: General molding sand.

Lab. No.: 18.
Location: Coosa river bottom at Riverside.
Producer: W. J. Stines.
Formation: Alluvial deposit.
Grade: General molding sand finer than 17.

Lab. No.: 19.
Location: Coosa river bottom at Riverside.
Producer: W. J. Stines.
Formation: Alluvial deposit.
Grade: Light pipe sand, fine.

Lab. No.: 20.
Location: Three-fourths mile N. E. of Cook Springs.
Producer: W. D. Carrecker.
Formation: Alluvial deposit.
Grade: Medium molding sand.

Lab. No.: 21.
Location: Three-fourths mile N. E. of Cook Springs.
Producer: W. D. Carrecker.
Formation: Alluvial deposit.
Grade: Heavy molding sand.

Lab. No.: 22.
Location: Three-fourths mile N. E. of Cook Springs.
Producer: W. D. Carrecker.
Formation: Alluvial deposit.
Grade: Core sand.

Lab. No.: 23.
Location: One-half mile S. of Cook Springs.
Producer: L. E. Shubert.
Formation: Alluvial deposit.
Grade: Molding sand.

Lab. No.: 24.
Location: One and one-fourth mile S. of Cook Springs.
Producer: D. W. Moody.
Formation: Alluvial deposit.
Grade: Light molding sand.

Lab. No.: 25.
Location: Near siding, Cook Springs.
Producer: H. E. Riggan.
Formation: Colluvial deposit, red loam.
Grade: Molding sand.

Lab. No.: 26.
Location: One-fourth mile S. E. of Cook Springs.
Producer: H. E. Riggan.
Formation: Alluvial.
Grade:. Molding sand.

Lab. No.: 27.
Location: West Anniston.
Producer: M. Griffis.
Formation: Colluvial deposit.
Grade: Red loam.

Lab. No.: 28.
Location: Ragland.
Producer: I. M. Sims.
Formation: Alluvial deposit.
Grade: Light molding sand.

Lab. No.: 29.
Location: Ragland.
Producer: I. M. Sims.
Formation: Alluvial deposit.
Grade: Heavy molding sand, red.

Lab. No. 30.
Location: Ragland.
Producer: I. M. Sims.
Formation: Alluvial deposit.
Grade: Core sand.

Lab. No.: 31.
Location: One-half mile N. E. of Irondale.
Producer: C. B. McDaniels.
Formation: Colluvial origin.
Grade: Medium red molding sand.

Lab. No.: 32.
Location: One-half mile N. E. of Irondale.
Producer: C. B. McDaniels.
Formation: Colluvial origin.
Grade: Heavy red molding sand or loam.

Lab. No.: 33.
Location: One-half mile N. E. of Irondale.
Producer: C. B. McDaniels.
Formation: Colluvial origin.
Grade: Core sand made by mixing.

Lab. No.: 34.
Location: Lorne siding, near Chelsea.
Producer: W. I. Whitfield.
Formation: Alluvial deposit.
Grade: Heavy molding sand.

Lab. No.: 35.
Location: Lorne siding, near Chelsea.
Producer: W. I. Whitfield.
Formation: Alluvial deposit.
Grade: Medium molding sand.

Lab. No.: 36.
Location: Lorne siding, near Chelsea.
Producer: W. I. Whitfield.
Formation: Alluvial deposit.
Grade: Light molding sand.

Lab. No.: 37.
Location: Lorne siding, near Chelsea.
Producer: W. I. Whitfield.
Formation: Alluvial deposit.
Grade: Core sand.

Lab. No.: 38.
Location: Irondale.
Producer: C. B. McDaniel.
Grade: Crushed Hartselle sandstone.

Lab. No.: 39.
Location: Argyle siding, near Chelsea.
Producer: M. B. Turner.
Formation: Alluvial deposit.
Grade: Core sand.

Lab. No.: 40.
Location: Argyle siding, near Chelsea.
Producer: M. B. Turner.
Formation: Alluvial deposit.
Grade: Light molding sand.

Lab. No.: 41.
Location: Argyle siding, near Chelsea.
Producer: M. B. Turner.
Formation: Alluvial deposit.
Grade: Medium molding sand.

Lab. No.: 42.
Location: Argyle siding, near Chelsea.
Producer: M. B. Turner.
Formation: Alluvial deposit.
Grade: Heavy red molding sand.

Lab. No.: 43.
Location: Washington Ferry, near Prattville.
Producer: H. H. Thomas.
Formation: Alabama River alluvial deposit.
Grade: Fine molding sand.

Lab. No.: 44.
Location: Washington Ferry, near Prattville.
Producer: H. H. Thomas.
Formation: Alabama River alluvial deposit.
Grade: Medium molding sand.

Lab. No.: 45.
Location: Jackson's Lake Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Alluvial origin.

Lab. No.: 46.
Location: Jackson's Lake Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Alluvial origin.
Grade: Pipe shop sand.

Lab. No.: 47.
Location: Jackson's Lake Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Alluvial origin.
Grade Building sand.

Lab. No.: 48.
Location: Near Coosada Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Colluvial origin.
Grade: Heavy red loam.

Lab. No.: 49.
Location: Near Coosada Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Colluvial orgin.
Grade: Open red molding sand.

Lab. No.: 50.
Location: Prattville Junction.
Producer: Underwood & Walker.
Formation: Alluvial origin.

Lab. No.: 51.
Location: Prattville Junction.
Producer: Underwood & Walker.
Formation: Alluvial origin.
Grade: Building sand.

Lab. No.: 52.
Location: Prattville Junction.
Producer: Underwood & Walker.
Formation: Alluvial origin.
Grade: Pipe shop sand.

Lab. No.: 53.
Location: Near Coosada Station.
Producer: Kirkpatrick Sand & Cement Co.
Formation: Alluvial origin.
Grade: Big bed sand.

Lab. No.: 54.
Location: Five miles W. of Montgomery.
Producer: Alabama Sand & Gravel Co.
Formation: Alluvial desposits of Alabama River.

Lab. No.: 55.
Location: Five miles W. of Montgomery.
Producer: Alabama Sand & Gravel Co.
Formation: Alluvial desposits of Alabama River.

Lab. No.: 56.
Location: North Montgomery.
Producer: Roquemore Gravel Co.
Formation: Alabama River alluvial deposit.

Lab. No.: 57.
Location: North Montgomery.
Producer: Roquemore Gravel Co.
Formation: Alabama River alluvial deposit.

Lab. No.: 58.
Location: Toulminville, Mobile.
Producer: Toulmin & Son.
Formation: Colluvial deposit.
Grade: Red sand or loam.

Lab. No.: 59.
Location: Toulminville, Mobile.
Producer: Toulmin & Son.
Formation: Alluvial.
Grade: Building sand.

Lab. No.: 60.
Location: Toulminville spur, Toulminville, Mobile.
Producer: Toulmin & Son.
Formation: River bank sand.

Lab. No.: 61.
Location: Dredged at 14 Mile Island, above Mobile.
Producer: Mobile & Gulf Navigation Co.
Formation: River sand.

Lab. No.: 62.
Location: 14 Mile Island, above Mobile.
Producer: Mobile & Gulf Navigation Co.
Formation: Bank sand from below 14 Mile Island.

Lab. No.: 63.
Location: Mobile Bay. Arlington docks, below Mobile.
Formation: River sand. Represents rain leached sand dredged on Mobile Bay. No producers.

Lab. No.: 64.
Location: Water works switch, beyond Springhill, near Mobile.
Producer: Mobile Pulley & Machine Works.
Formation: Lafayette.
Grade: Red loam.

Lab. No.: 65.
Location: Water works switch, beyond Springhill, near Mobile.
Producer: Mobile Pulley & Machine Works.
Formation: Lafayette.
Grade: Core sand used both in iron and steel casting.

Lab. No.: 66.
Location: Flomaton.
Producer: Escambia Sand & Gravel Corp.
Formation: Alluvial deposit.

Lab. No.: 67.
Location: One mile E. of Chehaw.
Producer: S. L. Brewer.
Formation: Alluvial deposit.
Grade: Pipe sand.

Lab. No.: 68.
Location: Chehaw spur.
Producer: Chehaw Sand & Gravel Co.
Formation: Alluvial deposit.

Lab. No.: 469.
Location: One and one-half miles E. of Red Bay.
Producer: Silica Mining Co.
Formation: Colluvial sand. Clay substance, after shaking much flocculated. No pebbles on 40-270, many muscovite mica flakes.
Grade: Red loam top of cut.

Lab. No.: 470.
Location: One and one-fourth miles E. of Red Bay.
Producer: Silica Mining Co.
Formation: Lafayette. Fine purple sand.
Grade: Many muscovite flakes on 40 and 70; a few on 100—through 270. Fine purple sand.

Lab. No. 471.
Location: One mile E. of Red Bay. Varigated sand, upper part of cut.
Producer: Silica Mining Co.
Formation: Tuscaloosa. Much fine clay, many mica flakes on 70 to through 270.
Grade: Molding sand.

Lab. No.: 472.
Location: One mile E. of Red Bay. Purple sand, lower part of cut.
Producer: Silica Mining Co.
Formation: Tuscaloosa. Many mica flakes on 40 to through 270.
Grade: Molding sand.

Lab. No.: 473.
Location: W. of Red Bay, just over line in Mississippi.
Producer: Golden Gravel Company.
Formation: Alluvial terrace on Bear Creek. Many quartzite pebbles averaging ¼ inch diam. This farm about 12 per cent of sand.

Lab. No.: 474.
Location: Same location as 473.
Producer: Golden Gravel Co.
Formation: Alluvial river terrace.

Lab. No.: 475.
Location: Spruce Pine.
Producer: Spruce Pine Sand and Gravel Co.
Formation: Tuscaloosa. About 5 per cent of sand is quartzite pebbles, averaging ¼ inch diameter; a little mica.

Lab. No.: 476.
Location: Spruce Pine.
Producer: Spruce Pine Sand and Gravel Co.
Formation: Tuscaloosa.

Lab. No.: 477.
Location: Spruce Pine.
Producer: Spruce Pine Sand and Gravel Co.
Formation: Tuscaloosa.

Lab. No.: 478.
Location: Spruce Pine.
Producer: Spruce Pine Sand and Gravel Co.
Formation: Tuscaloosa.
Grade: Stove sand.

Lab. No.: 479.
Location: Spruce Pine.
Producer: Spruce Pine Sand and Gravel Co.
Formation: Tuscaloosa.
Grade: Molding sand.

Lab. No.: 480.
Location: Berrylum.
Producer: J. W. Berry of Flomaton.
Formation: River bar sand washed. Contains a few quartz pebbles about ¼ inch diameter.

Lab. No.: 481.
Location: Florence.
Formation: River sand. Pebbles of chert and quartzite, about ¼ inch diameter, form about 18 per cent of the sand. These were screened out. There are a few mica flakes of all sizes.

Lab. No.: 482.
Location: Hobbs Island, Tennessee River.
Producer: Huntsville Transfer & Building Material Company.
Formation: River sand. Dredged from the point of Hobbs Island by a drag line bucket in Tennessee River. Contains a few mica flakes.

Lab. No. 483.
Location: Same as 482.
Formation: River sand; contains a few chert pebbles and a few mica scales.
Grade: Pipe sand.

Lab. No.: 484.
Location: Four miles W. of Adger, in Mud Creek.
Producer: J. L. Skates.
Formation: Colluvial deposit.
Grade: Pipe sand.

Lab. No.: 485.
Location: Tuscaloosa.
Producer: Bake Towboat Company.
Formation: River sand. Quartz pebbles, averaging about ¼ inch diameter, make up about 17 per cent of the sand. A few mica flakes from 70 to through 270. Dredged from river at Tuscaloosa between wagon and railroad bridges.

Lab. No.: 486.
Location: Same as 485.

Lab. No.: 487.
Location: Grace Station.
Formation: Colluvial deposits; contains a few pebbles of decomposed shale about ⅓ inch diam.
Grade: Radiator sand.

Lab. No. 488.
Location: Woodstock.
Producer: Greeley mines of Tennessee Coal & Iron Co.
Formation: Colluvial deposit overlying Tuscaloosa formation.
Grade: Red loam with a few quartzite pebbles.

Lab. No. 489.
Location: Same as 488.
Grade: Steel sand. Used for steel castings at Fairfield Works of Tennessee Coal & Iron Co. Contains a few quartz pebbles about ¼ inch diameter. A few mica flakes in all sizes from 70 to through 270.

Lab. No. 490.
Location: Three miles N. E. of Bessemer.

California

Lab. No: 1.
Location: Deposit is situated three miles west of Pacific Grove on the 17-mile Drive, between Pacific Grove and Carmel, and is on a spur track of the Southern Pacific Railroad, Monterey Co.
Producer: Del Monte Properties Co.
Formation: It consists of wind-blown sand dunes adjacent to the coast at Moss Beach, and extends along the coast for several miles, the quantity being practically unlimited. The dunes are of large size and remarkable uniformity of composition, although spots are occasionally found where storms of unusual severity have laid down a thin stratum of material either coarser or finer than the average. There is little or no overburden, and the deposit is unconsolidated.

It is worked by drag-line excavator, and is neither a strictly bank or pit operation. The sand may be loaded direct on railroad cars or passed through the plant for cleaning. In the plant the sand is passed over special concentrating tables of about twice the standard length for the removal of garnet, mica, iron, and dirt, using fresh water wash. It is then steam-dried by indirect heat and run through a special air separator for removal of the last traces of mica. It then goes to storage and is ready for sacking or run to cars. Only a very small percentage is sold as pit run, nearly all being treated before marketing.
Grade: Production is utilized for glass-making, molding sand, building sand (concrete, mortar, and stucco), as blast sand, roofing sand, filter sand, and other miscellaneous uses.

Lab. No.: 2.
Location: This is a beach deposit situated four miles south of the dunes from which the sand of sample No. 1 is obtained. This particular sand is obtained from a narrow inlet extending only a few hundred yards along the beach, but much farther inland. It is raised by drag-line scraper to bins and then hauled by a fleet

of 5-ton motor trucks to the plant for treatment.

The amount of sand available here is also practically unlimited.

Producer: Del Monte Properties Co.

Grade: Beach sand.

Lab. No.: 3.

Location: The deposit is situated one mile north of the Southern Pacific Railroad Station at Ventura, in T. 2 N., R. 23 W., S. B. B. M.: elevation, 250 ft. on the ridge south of Buena Vista Canyon.

Producer: Charles A. Cole, Ventura.

Formation: The deposit consists of unconsolidated sandy loam, fine grained sand, and shows a well-defined stratum, occasionally mixed with shells, that is about 100 ft. thick.

The material is worked by open quarry on the sand, 200 ft. in length and 100 ft. in height, and is handled with scraper to bins, then screened through No. 4 mesh trommel, oversize going to small set of rolls, then to loading bins, and hauled in wagons to the Southern Pacific depot at Ventura. Forty-five cars a month are shipped to foundries at San Francisco and Los Angeles.

Grade: Ventura velvet molding sand.

Lab. No.: 4.

Location: This deposit is situated within the Riverside City Limits, one-quarter mile northwest of Jurupa Station on the Salt Lake Railroad, in Sec. 29, T. 2 S., R. 5 W., S. B. B. M.: elevation 850 ft. on the south bank of the Santa Ana River.

Producer: Harry E. Blood, Citizens National Bank Building, Los Angeles.

Formation: The deposit consists of fine-grained sandy loam, which is 6 to 20 feet thick, covering an area of about five acres.

The surface soil is taken off, and the sand is handled with scrapers, which dump the material into a hopper, and it is then conveyed by an 18 in. by 20 ft. long belt conveyor, to a shaking screen over the railroad cars, where it is screened to one-quarter mesh. Six to eight cars a month are shipped to foundries in southern California in the vicinity of Los Angeles.

Grade: Jurupa molding sand.

Lab. No.: 5.

Location: Near San Diego, San Diego County.

Producer: Forrest L. Hieatt.

Grade: Hieatt No. 1.

Lab. No.: 6.

Location: Near San Diego, San Diego County.

Producer: Forrest L. Hieatt.

Grade: Hieatt No. 2.

Lab. No.: 7.

Location: Near San Diego, San Diego County.

Producer: Forrest L. Hieatt.

Grade: Hieatt No. 3.

Lab. No.: 8.

Location: Near San Diego, San Diego County.

Producer. Forrest L. Hieatt.

Grade: Hieatt No. 4.

Lab. No.: 9.

Location: The deposit is situated four miles southwest of Corona; two miles southwest of Lincoln siding on the Santa Fe Railroad, Sec. 11, T. 4 S., R. 7 W., S. B. B. & M.: elevation 2000 ft. in foothills of Santa Ana Range of Mountains.

Producer: Jackson and Haven, Riverside.

Formation: The deposit consists of a stratum of white molding sand, which occurs on the north side of Lord's Canyon, with a general strike N. W. and S. E. The stratum is about 30 ft. thick. The sand is white in color, 12 feet high and 25 feet in width, and is covered with about two feet of gravel and soil overburden. The grains of sand are sub-angular and well consolidated.

The deposit is worked by open cut, the material is broken down, loaded into cars and transported to loading bins.

Grade: White molding sand.

Lab. No.: 10.

Location: The deposit is situated four miles southwest of Corona, and two miles southwest of Lincoln siding on the Santa Fe Railroad in Sec. 10, T. 4 S., R. 7 W., S. B. B. M.; elevation, 1,500 ft. in the foothills of the Santa Ana Range of Mountains.

Producer: E. R. Nonholf, 1116 Ramona Ave., Corona.

Formation: Deposit occurs in unconsolidated sands, gravels and clays. Bedded deposit of sand, 50 ft. thick, covered with an overburden of gravel and soil 5 ft. thick. About 2 acres of ground will cover the deposit. Open cuts, and tunnel 50 ft. in length.

Grade: Molding sand.

Lab. No.: 11.

Location: The deposit is located in Sacramento County, adjoining the main line of the Southern Pacific Railroad, about 4 miles east of Sacramento, in Sec. 16. T. 9 N., R. 5 E., M. D. M., near Ben Ali. There is a spur track to the property from the Southern Pacific Company's main line.

Produced: Cannon & Co., Forum Building, Sacramento.

Formation: The deposits are irregular in area and depth and the operators have found it impossible to estimate the tonnage available in any particular bodies until they are worked. The deposits range from 1 to 3 feet in depth and are overlain by only six inches of turf. These deposits cover little knolls but do not occur in the lower portions of the ground. The individual bodies are usually not more than an acre or so each. They are quite uniform in quality.

The grains are angular sand fragments, mixed with clay, and form a free running sandy loam when dry, but are slightly consolidated when wet.

The turf is scraped off, the loam is plowed and delivered to a belt conveyor by a drag-line scraper. The sand is loaded into wagons and hauled one-fourth of a mile, where it is dumped into a bucket elevator, which loads it directl y into the railroad cars. The deposit is being worked for the molding sand.

Grade: Sacramento molding sand.

Lab. No.: 12.

Location: Deposit is situated on Alameda Creek, about 1½ miles west of Decoto, Alameda County, the nearest railroad shipping point.

Producer: Geo. Small, Niles, Alvarado Creek Road.
Formation: On the east side of the creek an area of about 5 acres had a levee thrown around it to impound water from the creek which annually overflows during the winter and spring rainy season. The overflow of this creek deposits new soil on much of the farming land in this vicinity. In the area within the levee fine sand and clay is deposited by the swirl of the water carrying the detritus, and as the water drains off, the material left is utilized as molding sand. It varies somewhat in texture, according to the part of the impounding area from which it is taken. It is shoveled direct from the deposit to wagons or trucks and hauled to the railroad at Decoto. Production is small and incidental to farming operations. Similar deposits have been found at other points where the creek has overflowed.
Grade: Fine molding sand.

Maryland

Lab. No.: 1.
Location: About one-half mile N. W. of Halethorpe. Within one-fourth mile of Washington Boulevard on the E. and an equal distance from the B. & O. on the W.
Producer: Pit of Benjamin Wade.

Lab. No.: 2.
Location: Mt. Winans on Washington Boulevard about one-fourth mile E. of the B. & O. R. R.
Producer: Pit of Beal Cook.

Lab. No.: 3.
Location: On the Severn River about one-fourth mile below Whitney's Landing. It is one-half mile S. of Robinson station on the W. B. & A. Short Line R. R.
Producer: Pit of the Brennan Sand Company.

Lab. No.: 4.
Location: Occurs below No. 3 and is 25-30 feet thick.
Producer: Pit of Brennan Sand Company.

Lab. No. 5.
Location: Little Round Top Mountain, three miles N. of Hancock. B. & O. runs around S. end of the mountain where the sand is being worked in two pits.
Producer: Pit of J. Funkhauser.

Lab. No.: 6.
Location: Rock Forge, about four miles S. W. of Waynesboro, Pa. Situated within one-fourth mile of highway and three miles from Western Maryland R. R.
Producer: Pit of A. A. Foltz.

Michigan

Lab. No.: 236.
Lab. No.: 700, Mich., No. 501.
Producer: Whitehead Bros., Sand Dunes.
Location: Six miles out of Cheboygan on County road to Grace and Orchard Lake. Section 15, T. 37 N. R. 1 W., Cheboygan County.
Formation:—Lake deposited gravelly, sand about 30-40 ft. or more. Sample taken from upper 6 ft. on property of Apple Growers' Association. Red and yellow sand and white sand of rather coarse texture. Deposit covers 30-40 sq. miles. Contains a few quartzite and granite pebbles, about ¼ inch diameter.

Lab. No.: 701, Mich., No. 502.
Location: Black Lake District, T. 36 N. R. 1 E., Cheboygan County.
Formation: Clean white sand; 6-8 ft. or more in depth over considerable area (10-15 sq. miles) in district around Black Lake.

Lab. No.: 702, Mich., No. 503.
Location: Four and one-half miles S. of Onaway and through the Plains. All Sec. 31-32, T. 34 N. R. 2 E., Presque Isle.
Formation: Somewhat pebbly yellow sand through center of Sec. 31 and 32, at Township line; it is covered by hill of drift. The sand seems to be drift of variable thickness from 3 to 4 feet or more in plains to South. Sample from pits sunk into sand bed. Same sand continues South through plains, running light on ridges and thicker in valleys or hollows. A few pebbles of quartzite and fossiliferous limestone about ¼ inch diameter.

Through T. 34 N., underlain by red clay at 3 or 4 ft. depth. South of T. 34 N. sand is much thicker.

Lab. No.: 703, Mich., No. 504.
Location: All Sec. 24, T. 30 N. R. 1 E. (N. W. corner), Bigelow, Montmorency County.
Producer: Bigelow, Kneeland-Bigelow County., Mr. Lundeen, V. P.
Formation: Light yellow or white sand extending in ridge N. E. of R. R. and running N. N. W. from South center of Sec. 24 through Sec. 14. At the N. W. end of 14 it gets very gravelly.

Gravel in mound S. and S. W. of R. R., running through Sec. 15, 23.

The boulder clay charted for T. 29 N., R. 1 E., is covered with sand.

Around the Twin Lakes the sand is white beach sand, similar to the plains sands, found N. of Atlanta and West, toward Gaylord, in Otsego County.

Lab. No.: 704, Mich., No. 505.
Location: Lewiston. All Sec. 34, 35, T. 29 N., R. 1 E., Montmorency County.
Formation: Gravel and sand over large area (40-80 sq. miles). Samples from pit 5 ft. deep. About 36 per cent pebbles, consisting of quartzite, sandstone, shale and granitic rocks, about ⅓ inch diameter; some of the pebbles are over 2 inch diameter.

Lab. No.: 705, Mich., No. 506.
Location: Snyder's Resort, near Bear Lake. Sec. 21 and 22 (all) and S. T. 27 N., R. 1 E., Oscoda County.
Formation: White and light yellow sand, gravelly in spots and contains lumps of yellow clay. The sand is of varying depths, but runs up to 15 or 20 ft., generally. The same sand extends on South through the plains over 50 or more sq. miles. A few pebbles of limestone quartzite and gneiss about ⅓ inch diameter. Sample from pits sunk into sand.

Lab. No.: 706, Mich., No. 507.
Location: Luzerne (one-half mile N.). All Sec. 23 (N. E.), T. 26 N., R. 1 E., Oscoda County.
Formation: Light yellow to white sand of varying depth, over large area through this district. Runs about 6 ft. deep or more, generally. Sample from pits and auger borings.

Lab. No.: 707, Mich., No. 509.
Location: All Sec. 23, 24, 25, 26, T. 30 N., R. 7 E., Alpena County.
Formation: Light yellow sand of varying depth throughout this district. Seems somewhat similar to sand found further inland on the plains.

Lab. No.: 708, Mich., No. 510.
Location: Lachine, one mile N. Sec. 8, 19, 16, 17, T. 31 N., R. 6 E., Alpena County.
Formation: Few inches of white sand, then a few inches of brown sand containing chunks cemented together, apparently by iron oxide. These chunks are deeper in color and are found under a few inches of the white sand which seems to extend down into brown sand, much as if the iron oxide that acts as a bond had been leached out of the white sand above. In about 3 ft. the sand runs to typical yellow plains sand. Sand of this type found in the immediate vicinity has been used in past for molding sand in making brass castings.

Lab. No.: 709, Mich., No. 511.
Location: Sec. 4, T. 31 N., R. 6 E., Alpena.
Formation: Clayey sand. Boulder clay in considerable amount. A few pebbles of quartzite and limestone about ⅓ inch diameter. Seems to possess molding sand possibilities.

Lab. No.: 710, Mich., No. 513.
Location: Near Spruce, 8-9 miles W. of D. & M. R. R. All Sec. 6, T. 28 N., R. 8 E., Alcona.
Formation: Moraine containing stones of all sizes and sand and clay. The sand and clay seem well mixed and to possess molding sand possibilities. The sample was taken from trench and put at side of road, and is generally typical of district. A few pebbles of limestone and quartzite about ⅓ inch diameter.

Lab. No.: 711, Mich., No. 516.
Location: One mile N. of Edwards. Sec. 23, T. 21 N., R. 1 E., Ogemaw.
Formation: Sand, light yellow, somewhat stony on top, running through thin layers of clay about 3 ft. down into more sand of same nature. Sample from pit and auger, and is typical of district. A few pebbles, mainly of quartzite, about ⅓ inch diameter. Deposit covers 2 or 3 sq. miles.

Lab. No.: 712, Mich., No. 518.
Location: One mile W. of Billings. All Sec. 24, T. 17 N., R. 1 W., and Sec. 28, T. 17 N., R. 1 E., Gladwin County.
Formation: Yellow sand mixed with layers of red clay under 3 or 4 ft. of sand similar to No. 517.
Seems to be the clay that is running to sand.
Sample from face of bank.
Runs in a ridge S. E. through Larkin.

Lab. No.: 713, Mich., No. 519.
Location: All Sec. 28, T. 16 N., R. 1 E.
Formation: Sand, light yellow, rusty on top; hard limonite crusts and chunks through uniform sand, ½ in. white sand. 4/10 in. yellow sand. ⅜ in. limonite crusts.
Sand over 4 ft. thick. Sample from pit through limonite crusts and lower sand. Deposit covers a sq. mile or more.

Lab. No.: 714, Mich., No. 520.
Location: All Sec. 8-9, T. 13 N., R. 2 E., Midland.
Formation: Ridge of sand ¼ mile wide, running W. S. W. for ⅔ mile and noted before. Sample from pit 10 ft. deep.

Lab. No.: 715, Mich., No. 521.
Location: Three miles E. of Vassar, N. of P. M. R. R., locally. Sec. 15, T. 11 N., R. 8 E., Tuscola County.
Producer: Burt Com. Sand Company, Vassar. Walter R. Thompson Co., 604 Kerr Bldg., Detroit.
Formation: Fifteen ft. of sand in ridge dug and screened to remove roots, lumps, etc., and shipped as core sand. Reported that it is mixed with other sand (fine sand) for use in cores, and mixed with some clay and used as molding sand for aluminum casting.

Ship 6 cars a day going to Detroit, Flint, Saginaw, Lee, Saginaw Products Co. (Grey iron), Washington Ave., Saginaw.

Overburden of sand, few inches to a couple of feet removed, then comes a layer of rusty sand of a few inches and then 15 feet of core sand worked by steam shovel to dinky cars to screen to R. R. cars. Under the same is some white sharp sand. Sample from steam shovel diggings (A—screened, B—unscreened). Deposit covers 2 to 3 sq. miles of varying depth.

Seems as if original level was below core sand on top of white sand as there are roots and a rusty crust there, and the core sand was later blown or deposited up about 15 ft. over the old level, and later the core sand covered by more sand. The sand is called blow sand by the farmers because it is blown by wind.

The sand runs in a ridge N. E. and S. W., as if it might be an old sand bar, as it corresponds with old shore line in general direction.

Lab. No.: 716, Mich., No. 522.
Location: All Sec. 17, T. 11 N., R. 8 E., Tuscola.
Formation: Top 3 to 4 ft. of yellow sand. Sample from material excavated from trench, and is typical of soil sand in district.

Lab. No.: 717, Mich., No. 523.
Location: Just E. of Juaniata on P. M. R. R. Sec. 30, T. 11 N., R. 9 E., Tuscola.
Producer: Great Lakes Distributing Co.
Formation: Old water deposited sand as there are thin strips of clay about 4 to 6 in. apart through the sand, which give the scaly appearance to the dry bank.
"Bank sand." Covers 2 to 3 sq. miles.

Lab. No.: 718, Mich., No. 524.
Location: Just S. of P. M. R. R., 2 miles E. Silverwood. All Sec. 5-6, T. 10 N., R. 11 E., Lapeer.
Formation: Sandy (Moraine?) containing some pebbles. Sample from trench and pit in roadside. A few quartzite pebbles, about ¼ in diameter.

Lab. No.: 719, Mich., No. 525.
Location: On P. M. R. R. Sand bank. All Sec. 30, T. 7 N., R. 16 E., St. Clair.
Producer: Formerly owned by Fred Black, now by Otto City Sand & Brick Co., Homeseekers Realty Co. Bldg., Port Huron.
Formation: Not as good as that at Juaniata, not so uniform. In sand ridge running almost S., a little W. (1½ mile W. of Thornton)? Apparently abandoned. Only short siding. About 2 sq. miles.

Lab. No.: 720, Mich., No. 526.
Location: All Sec. 1, T. 6 N., R. 15 E., St. Clair.
Producer: A new sand pit just being opened up by Otto Sand & Brick Co. Have steam shovel and are putting in siding.
Formation: Sand seems more uniform than that near Abbotsford, but has considerable clay pockets. The layers containing clay are pronounced and closer than at Juaniata. Apparently they have abandoned the old pit opened by Black, two miles N. (sheet 529), and are developing this one. Sample from trench 8 ft. deep alongside of bank. Deposit 10-15 ft. deep and covers 2 sq. miles.

Lab. No.: 721, Mich., No. 527.
Location: All T. 7 S., R. 7 W., and T. 6 S., R. 7 W., branch.
Formation: Gravelly sand resembling bank sand in places (as sample 527) and running to clean washed gravel underneath. Appears to be lake deposit or outwash plains. The sample is generally typical of this district. But it varies to cleaner sharp sand places and to gravel. Sample of sand occurring in pockets totaling ½ sq. mile. A few pebbles of quartzite, shale and gneissic rocks averaging ⅓ inch diameter.

Lab. No.: 722, Mich No. 528.
Location: All Sec. 2-3, T. 8 S., R. 13 W., Cass.
Formation: Sand containing some clay and gravel running more clay at 8 to 10 ft. deep. A few pebbles, mainly quartzite, about an inch diameter. Sample by trenching bank on roadside for about 11 ft. from top. Deposit covers 2-4 sq. miles.

Lab. No.: 723, Mich., No. 529.
Location: All Sec. 12, T. 8 S., R. 14 W., Cass Co.
Formation: Sample from pit about 6 ft. deep into the sand, which makes up the soil through this immediate vicinity—contains some clay on top; less at lower depths. A few quartzite pebbles, mostly about 1/3 inch diameter.

Lab. No.: 724, Mich., No. 530.
Location: All T. 7 S., R. 21 W., Berrien Co.
Formation: Light yellow bank sand in sand bank alongside road. Sample taken from pit and trench and is typical of water deposited sand in the district. Large quantities of sand here, many miles.

Lab. No.: 725, Mich., No. 531.
Location: All Sec. 15, T. 6 S., R. 19 W., Berrien Co.
Formation: Till plains mostly sand some stones and a little clay. A few pebbles of shale and quartzite about 1/4 inch diameter. Sample from under 2 ft. Then runs to a coarser sharp sand containing pebbles, and is wet. In a few places there are clay ridges; report Garden City pits at Riverside, N. of Benton Harbor. Area 4 sq. miles.

Lab. No. 726: Mich., No. 532.
Location: Sec. 24, T. 3 S., R. 18 W.
Producer: Garden City Sand Co. of Chicago. Kerlikowske, operator.
Formation: Top foot clay loam and about 3-5 ft. of brown clay and sand mixed, underlain by white beach sand. Sample 532 is of the brown clay and sand mixed; 533 of white beach sand underneath. Top foot of loam is rejected and shoveled into pit as fill. Sandy clay is mixed with white beach sand in mixtures containing up to 50 per cent of white sand. Trucked 1/4 mile across road to siding of Pere Marquette. Material is shipped into Illinois, Wisconsin and other places. Dug over 20 acres in last 10 years. Put through crusher and screen to break up lumps and mix in sand before loading. Ships about three cars a day with six carts. More of same kind about 1/8 mile S. of railroad and also about 1/4 mile E. and S. of R. R. in Sec. 26, is pit of same kind of material containing more sand and easier to dig.
Grade: Molding sand.

Lab. No. 727: Mich., No. 533.
Location: Sec. 24, T. 3 S., R. 18 W.
Producer: Garden City Sand Co. of Chicago. Kerlikowske, operator.
Formation: Same as preceding.
Grade: Molding sand.

Lab. No.: 728, Mich., No. 534.
Location: All Sec. 32, T. 6 S., R. 12 W., St. Joseph County.
Formation: Sandy, pebbly drift—some clay, 1 to 2 ft. and typical of district to the W. About 14 per cent quartzite and gneiss pebbles; average diameter about 1/3 inch. Covers 5 sq. miles.

Lab. No.: 729, Mich., No. 534-A.
Location: All Sec. 18, T. 6 S., R. 7 W., Branch County.
Formation: Sandy, gravelly boulder clay. A few pebbles of quartzite about 1/4 inch diameter. Sample from pit 3 ft. deep in roadside. Sample apparently typical of the district.

Lab. No.: 730, Mich., No. 535.
Location: All Sec. 10, T. 6 S., R. 2 W., Hillsdale, just S. of N. Adams.
Formation: Boulder clay or sand—outwash till plains. Sandy, gravelly clay 5 ft. or more to hard pan (blue gray) which may be shale. A few quartzite pebbles averaging ⅓ inch diameter. Covers 5 sq. miles. Samples from trench and pit in roadside.

Lab. No.: 731. Mich. No. 536.
Location: T 5 S, R 1 W. Sec. 21, Hillsdale Co.
Formation: Sharp sand in bank on side of hill and about 50 feet thick.

Lab. No.: 732. Mich. No. 2003.
Location: Sand Bluffs, ½ mile from Coldwater River. Sec. 13, T 14 N, R 6 W.; Broomfield Twp., Isabella County.
Formation: Sample of sand was taken in a cut in the road. The sand was white, free from pebbles and at a depth of from 12 to 20 feet showed the same general characteristics. Top layer 2 to 3 feet sand, showed some gravel. Area, 15 to 20 square miles. Sharp sand.

Lab. No.: 733. Mich. No. 2004.
Location: Two miles N. E. of Mt. Pleasant. Sec. 2, T 14 N, R 4 W.; Isabella Twp., Isabella County.
Formation: Sample of yellow sand taken from side of road covered by reddish, rusty layer about 2 to 3 feet thick. About 6 per cent quartzite pebbles, average diameter 1 inch. Area covered about 20 square miles along Chippewa River. Sample of sand underneath rusty layer. Rusty top might be molding sand.

Lab. No.: 734. Mich No. 2005.
Location: Eight miles N. of Barryton; Sec. 15 and 16, R 7 W. T 17 N.; Orient Twp., Osceola County (Information from N. E. McMichael, of Sears, Mich.)
Formation: Yellow to white sand streaked with small deposits of red clay taken from side of road. Country to south low and swampy; to north hilly, full of dunes. Sample taken on the Dave Kibbe property. Sample by trenching and pit.

Lab. No.: 735. Mich. No. 2006.
Location: Sections 9 and 10, T 18 N. R 7 W.; Sylvan Twp., Osceola County.
Formation: Sample taken from bank of creek flowing into Muskegon River. Top layer 5 to 6 feet full of gravel, rest seemingly free from gravel; yellow to white sand. Area, 2 to 3 townships, along Muskegon River.

Lab. No.: 736. Mich., No. 2009.
Location: One mile S. of Lake City and ½ mile E. railroad; Sec. 7, T. 22N., R 7 W.; Reeder Twp., Missaukee County.
Location: A sample of sand was taken from the pit used by Mr. Minthorn for sand in his brick molds. The sand seems to be mixed with fine clay and to be free from gravel. A few pebbles of decomposed quarzite, average diameter, ¼ inch. The sample was taken about ½ mile down road from this brick yard. Bond clay. Pit 10 feet deep, sand from underneath clay. Sand in pockets. Sand around the district had been used for glass.

Lab. No.: 737, Mich. No. 2010.
Location: Sec. 6. T. 22 N., R. 4 W.; Roscommon Twp. A., Roscommon County.
Formation: The sample was taken from a deposit of white sand covered by yellowish sand. The yellowish sand was from 3 to 4 feet in depth and then white of unascertained depth. The deposit covered an area of 25 to 30 sq. miles.

Lab. No.: 738, Mich. No. 2011.
Location: South shore of Houghton Lake, about 10 miles from railroad; Sections 19 and 20, T. 22 N., R. 3 W.; Denton Twp., Roscommon County.
Formation: The sample was taken from a deposit of yellow sand covering a great many square miles south of Houghton Lake. The sand is free from stone or gravel and remains the same for at least 10 to 12 feet after the top layer of a few inches of darker sand is removed. A few quartzite pebbles, average diameter ¼ inch. The country is flat with a few low hills in some places. There were similar sand deposits all the way from Houghton Lake to Roscommon (along M. 14) with small outcroppings of boulder clay covered with sand. In some places the sand was white, similar to that taken near the Muskegon River. Smooth round grains.

Lab. No.: 739, Mich., No. 2012.
Location: Just outside city limits of Grayling to the N., near M. C. R. R.; Sec. 6. T. 27 N., R. 4 W.; Grayling Twp., County Crawford.
Formation: Similar sand to sample 2011, found throughout this country, yellowish to red changing to white below, showing about uniform for at least 35 feet in river bank and cuts. Deposit extends over large area.

Lab. No.: 740, Mich. No. 2013.
Location: Cuts in side of road and M. C. R. R. Cut near railroad; Sec. 20, T. 29 N., R. 3 W.; Otsego Twp., Otsego County.
Formation: Sample of yellowish sand covering a layer of white sand mixed with gravel. Sand underneath the top layer of 3 or 4 feet seems freer from stones. Sample came from low hills or dunes along M. 14 and M. C. R. R. Very little, if any bond. Smooth round grains. A few pebbles of quarzite, shale and granite. Average diameter ¼ inch.

Lab. No.: 741, Mich., No. 2014.
Location: One and one-half miles S. of Vanderbilt Station, on M. C. R. R.; Sec. 34, T. 32 N., R. 3 W.; Corwith Twp., Otsego County.
Formation: Yellow sand covering whitish sand, yellow 4 to 10 feet in thickness, white to a depth of at least 30 feet. Sample taken seems similar to that taken around Gaylord. Covered and mixed with some gravel, possibly clay underneath. Area 30 square miles or more. This kind of sand extends north of Vanderbilt through rest of Otsego County, and into Cheboygan County. Very little, if any, bond. Smooth round grains. About 5 per cent quartzite and shale pebbles; average diameter ⅓ inch. Some few are 1½ inch diameter.

Lab. No.: 742, Mich., No. 2014-A.
Location: Nearly four miles N. W. of Wolverine, M. C. R. R. along

Sturgeon River; N. E. ¼ Sec. 14, T. 34 N., R. 3 W.; Mentor Twp., Cheboygan County.

Location: Cut long west bank of Sturgeon River revealed layers of sand and gravel to a depth of 40 feet or more. First a 2 to 6 feet layer of gravel, then yellow sand for 8 to 10 feet; finally white sand for rest of depth. The sand lies in wooded dunes, all through the country, covering several sections. Smooth round grains, very little bond. Sample of white sand.

Lab. No.: 743, Mich., No. 2015.

Location: ¼ mile to ½ mile N. and W. of Mullett Lake station; Sec. 34 T. 37 N. R. 2 W.; Inverness Twp. Cheboygan County.

Formation: Sample of yellow to white sand taken from top of Hill, ¼ mile to ½ mile N. W. of Mullett Lake station. Seems similar to that obtained on Sturgeon River, smooth, round grains, very little bond. Pit in side of hill.

Lab. No.: 744, Mich., No. 2016.

Location: One and one-half miles S. W. limits of Mackinaw City and M. C. and G. R. & I. R. R.; Sec. 27, T. 39 N., R. 4 W.; Carp Lake Twp., Emmet County

Formation: Yellowish to whitish sand in layers about 10 to 20 feet deep, covering reddish clay. Clay coming to surface in places, extent of deposit 3 or 4 sq. miles or more. Smooth round grains, seems to have some bonding material. Taken from Brock's farm. Pit 6 to 8 feet. Brock said sand was usable for foundry sand.

Lab. No.: 745, Mich., No. 2017.

Location: One-half mile S of Mackinaw City, along M 10; 2 miles from M. C. and G. R. & I. R. R.; Sec. 24, T. 39N., R. 4 W.; Carp Lake Twp., Emmet County.

Formation: Yellowish to whitish sand, smooth round grains; sample taken from a cut in the road showing 20 to 30 feet of same stuff. This sand is streaked with limestone which outcrops in a strip 1 to 2 miles along lake shore. Streaks of clay in many places. Bond probably clay. A few quartzite pebbles averaging ¼ inch diameter. Sampled by trenching.

Lab. No.: 746, Mich., No. 2018.

Location: Five miles N. of St. Ignace, along lake shore and M 12; two and one-half miles from D. S. S. & A. R. R.; Sec. 13, T. 41 N., R. 4 W.; Moran Twp., Mackinac County.

Formation: Sample of yellow sand streaked with white from a cut in the road. The sand has round grains and there is a little bonding material present. The depth is at least 15 to 20 feet. The area of several square miles is confined to a strip a mile or so wide along the lake shore and M. 12. Plain sand, sampled by trenching.

Lab. No. 747, Mich., No. 2019.

Location: Three and one-half miles from Hessel, on the lake; 28 miles from D. S. S. & A. R. R. at St. Ignace; Sec. 49, (?), T. 42 N., R. 1 W.; Marquette Twp., Mackinac County.

Formation: Sand similar to that near St. Ignace. Area seems to run along the lake from St. Ignace to Hessel, 10 to 20 miles. White, sharp sand; no bond.

Lab. No.: 748, Mich., No. 2020.
Location: Thirteen miles S. of Soo, on M 12, and five and one-half miles E. of Minn. St. Paul & Soo R. R., seven miles from Hay Lake; Sections 13 and 18, T. 45 N., R. 1 W. and 1 E.; Bruce Twp., Chippewa County.
Formation: Reddish yellow sand over white, underlaid by clay at a depth of 10 to 20 feet; smooth round grains, with clay bonding material. Area probably covers 20 to 30 square miles. A few pebbles of decomposed shale averaging about ¼ inch diameter. Pit.

Lab. No.: 749, Mich., No. 2021.
Location: Three miles S. E. of Brimley on the D. S. S. & A. R. R.; Sec. 21, T. 46 N., R. 2 W.; Superior Twp., Chippewa County.
Formation: Whitish sand overlaying clay to a depth of 4 to 15 feet, same area as Brimley clay deposit. Fine, smooth, grains; probably clay as bonding material. Area covers several square miles. A few pebbles, chiefly decomposed shale about ⅓ inch diameter.

Lab. No.: 750, Mich., No. 2022.
Location: Three miles N. of Minn. St. Paul & Soo R. R.; Sec. 16, T. 45 N., R. 2 W.; Kinross Twp., Chippewa County.
Formation: White sand covering yellow sand, smooth round grains with seemingly little bonding material. Deposit extends E. and W. over large area. Considerable depth.

Lab. No.: 751, Mich., No. 2023.
Location: One-eighth mile from Minn. St. Paul & Soo R. R. near spur to Scott Quarry; Sec. 20, T. 44 N., R. 4 W.; Trout Lake Twp., Chippewa County.
Formation: Yellow sand, smooth grains, some bonding. Material depth unascertained, but at least 20 feet. Sand is streaked with white sand in places. Country low and level; nearly barren of trees. Very large area, probably several sections. Plain sand. A few pebbles of sandstone and quartzite averaging ¼ inch.

Lab. No.: 752, Mich., No. 2040.
Location: Cut along M. 48 on D. S. S. & A. R. R., ½ mile E. of Trout Lake Junction; Sec. 23, T. 44 N., R. 6 W.; Trout Lake Twp., Chippewa County.
Formation: Yellow sand to a depth of at least 30 feet, as shown in cut covered by about 6 inches of gray sand. Round grains, very little bonding material, about the same as sample 2023.

Lab. No.: 753, Mich., No. 2025.
Location: Two miles N. of Minn. St. Paul & Soo R. R.; Sec. 21, T. 44 N., R. 8 W.; Hudson Twp., Mackinaw County.
Formation: Sand similar to sample taken near Trout Lake; No. 2024. Depth at least 8 to 10 feet. Large area of this sand overlying limestone in this region. Some cuts show layers of clay and quick sand at a depth of 15 to 20 feet. A few pebbles of quartzite, decomposed sandstone and limestone, averaging ¼ inch.

Lab. No.: 754, Mich., No. 2026.
Location: One-quarter mile S. of Dollarville, D. S. S. & A. R. R. along M. 25; Sec. 23, T. 46 N., R. 10 W.; Pentland Twp., Luce County.

Formation: Yellow sand, overlying red to white sand at a depth of 10 feet. The depth of lighter sand undetermined. Area seems to extend around Newberry and Dollarville for a number of square miles. Smooth grain with possibly some bonding material. Layers of sand seem free from gravel.

Lab. No.: 755, Mich., No. 2027.
Location: Six miles S. E. of Seney & D. S. S. & A. R. R.; Sec. 13, T. 45 N., R. 13 W.; Germfast Twp., Schoolcraft County.
Formation: Sample of red sand taken from cut 20 to 25 feet deep; sand in layers, some bonding material round grains. Country looks as if the sand bluff might be underlaid with clay. Depth of deposit unascertained.

Lab. No.: 756, Mich., No. 2028.
.Eleven miles N. of Seney; Sec. 4, T. 47. N., R. 13 W.; Seney Twp., Schoolcraft County.
Formation: Dark yellow sand streaked with white to a depth of 8 to 10 feet. Very compact layers. Smooth round grains with some bond. Clay subsoil. Red clay at depth of 15 to 20 feet in some places.

Lab. No.: 757, Mich., No. 2029.
Location: Six and one-half miles N. of Seney, on M. 77 and D. S. S. & A. R. R., on bank of Creek; Sec. 22, T. 47 N., R. 13 W.; Seney Twp., Schoolcraft County.
Formation: Yellow sand mixed with gravel, rather sharp grains. Cut in bank of creek shows 30 to 40 feet of this sand. Area reaches into Seney. Country pine barrens, mostly flat, with some dunes. About ten per cent pebbles averaging ⅓ inch diameter, including quartzite, sandstone, slate, schist, granite, gneiss, quartz, prophyry.

Lab. No.: 758, Mich., No. 2030.
Location: About twelve miles N. E. of Munising and six miles from Lake Superior on M. 25, detour; Sec. 15, T. 47 N., R. 17 W.; Munising Twp., Alger County.
Formation: Yellow sand taken from side of road over hardpan, total depth at least 10-15 ft.; then clay and quicksand in some places and in one place of reddish material. A few pebbles of decomposed sandstone and limestone, averaging ⅓ inch diameter. Area is very large as we drove 10-15 miles over seemingly same kind of soil.

Lab. No.: 759, Mich., No. 2031.
Location: Four miles E. of Munising and Munising Bay; five and one-half miles from D. S. S. & A. R. R.; Sec. 34, T. 47 N., R. 18 W.; Munising Twp., Alger County.
Formation: Reddish sand taken from 35-40 ft. cut on road M 25 detour. Sand is in distinct layers, compact as if laid by water, fine grained, reddish to white in places and seems very homogeneous; some bonding material. A few pebbles of decomposed sandstone, granite and quartzite, about ¼ inch diameter. Area unascertained, but seemingly quite large, as sand is the same in numerous low hills throughout this region. Deposit extends across the D. S. S. & A. R. R.

Lab. No.: 760, Mich., No. 2031-A.
Location: W. of Munising on M 25 and 1/4 mile from South Eastern R. R. Grade separation. Sec. 36, T. 46 N., R. 20 W Au Train Twp., Alger County.
Formation: White sand filled with gravel in places, shows depth of 25-30 ft. in cut, 4-6 ft. of yellow sand as top covering. Very little bonding material. Rather sharp grains. About 11 percent pebbles, averaging 1/3 inch diameter, but same up to 1 1/2 inch and consisting of gneiss, quartzite, limestone and granite. Probable extent of deposit 8-10 sq. miles.

Lab. No.: 761, Mich., No. 2032.
Location: One and one-half miles W. of Marquette Southern R. R. on M 25, three miles N. W. of Scandia. Sec. 1, T. 46 N., R. 24 W. West Branch Twp., Marquette County.
Formation: Pink sand covered by 3-4 ft. of yellow sand in layers, very compact, smooth round grains, some bonding material, similar to sand sample No. 2031, near Munising. Quite large area, extending almost to Marquette, 30-40 sq. miles.

Cleveland Cliff Iron Works, Marquette, Mich., get their foundry sand from Carp River about three miles out of Marquette. Enough left for one year supply. Have taken sand from this place for past 16 years. It is an ordinary yellow sand, like a great many of the samples taken. They tried beach sand, but it did not work because of no bonding material. They use the sand in casting pig iron.

Lab. No.: 762, Mich., No. 2033.
Location: At Eagle Mills, on M 25 and D. S. S. & A. R. R. and the Munising R. R. Sec. 34, T. 48 N., R. 26 W. Negaunee Twp., Marquette County.
Formation: Large dunes of yellow sand to depth of at least 30-40 ft. Rather sharp grains with some bonding material. A few pebbles of quartzite, slate and gneiss, averaging 1/4 inch diameter. Sand seemingly uniform in compact layers. Large area, possibly several sq. miles.

Lab. No. 763, Mich., No. 2034.
Location: One-fourth mile from Lake Superior and one and one-half miles from D. S. S. & A. R. R., along M 25. N. E. 1/4 Sec. 26 T. 53 N., R. 33 W. Chassell Twp., Hóughton County.
Formation: Red sandstone, very compact and hard, occurs in ridges along the shore of Lake Superior. Fine grains, some bonding material. Overlaid in some places with a few feet of loose yellow sand. One cut at side of road showed a depth of 35-40 ft. Area rather extensive. Deposit occurs in layers.

Lab. No.: 764, Mich., No. 2035.
Location: Along W. side of river, two miles W. of Houghton. Sec. 28, T. 55 N., R. 34 W. Stanton Twp., Houghton County.
Formation: Sample of red sand streaked with clay from cut, which showed a depth of about 25-30 ft. Sand not uniform, being streaked with stone, clay, gravel and hardpan, and some white sand. A few pebbles of slate, average diameter 1/4 in. Area extends N. and W. along Lake Superior, probably covers 30 sq. miles. Smooth grains with some bonding material.

Lab. No.: 765, Mich., No. 2037.
Location: One mile S. W. Parnsdale, along M 25. Sec. 36, (N. E. ¼); T. 54 N., R. 35 W. Adams Twp., Houghton County.
Formation: Low hills of red sand, very compact layers, more or less mixed with stone. Cuts show depth 10-30 ft. with rocks jutting out in places. A few sandstone and gneiss pebbles, average ⅓ inch diameter. Area seems quite extensive extending along M 26 for about ten miles.

Lab. No.: 766, Mich., No. 2038.
Location: On S. side of Copper Range R. R. S. E. ¼. Sec. 29, T. 52 N., R. 36 W. Elm River Twp., Houghton County.
Formation: Yellow sand, mixed with gravel in some places, very little bonding material, sharp grains. Cuts show depth at least 20-25 ft. area about 20 sq. miles. Sand covered by 3-4 ft. of gravel.

Lab. No.: 767, Mich., No. 2039.
Location: One mile S. of Paulding & Chicago & N. W. R. R., along M 28. Sec. 15, T. 46 N., R. 39 W. Haigh Twp., Ontonagon County.
Formation: Yellow sand, sharp grains, some bond, with stone and gravel in some places at a depth of 4-15 ft. over red clay. A few pebbles, mainly of quartzite and gneiss, about ¼ inch diameter. Area about 10-12 sq. miles.

Lab. No.: 768, Mich., No. 2040.
Location: Three fourths mile W. of Gogebic station on Chicago & N. W. R. R. Sec. 26, T. 46 N., R. 42 W. Marenisco Twp., Gogebic County.
Formation: Yellow sand, sharp grains, to a depth of at least 15-20 ft. from cut in road; sand in layers, compact with some bonding material. Mixed with layers of reddish sand in some places.

Lab. No.: 769, Mich., No. 2041.
Location: One mile S. of Watersmeet, along C. & N. W. R. R. and M 12. Sec. 27, T. 45 N., R. 39 W. Watersmeet Twp., Gogebic Co.
Formation: Yellow, sharp-grained sand, possibly with some bonding material 10-15 ft. in depth at least. Area about 10-20 sq. miles around Watersmeet. Seemingly free from stones. A few quartzite pebbles, averaging ¼" diameter.

Lab. No.: 770, Mich., No. 2042.
Location: One mile S. of Crystal Falls; one-half mile from branch of C. M. & St. P. R. R. Sec. 32, T. 43 N., R. 32 W. Crystal Falls Twp., Iron Co.
Formation: Yellow sand streaked with a little white and containing some stone. A few pebbles of quartzite and gneiss, from ¼" to 1" diameter. Area about 40-50 sq. miles. Depth in cut 30-35 ft. Further depth unascertained.

Lab. No.: 771, Mich., No. 2043.
Location: One-fourth mile N. Menominee River and State Line on M 12; one and one-half W. of C., M. & St. P. R. R. and five miles N. of Iron Mt. Sec. 1, T, 40 N., R. 30 W. Breitung Twp., Dickinson Co.
Formation: Yellow, smooth, fine grained sand with some bonding material. A few pebbles of quartzite sandstone and shale. Area unascertained; is mixed in some places with stone and sandy

gravel. Depth at least 10-15 ft. One cut along river showed depth 30-40 ft.

Lab. No.: 772, Mich., No. 2044.
Location: Along M 91, near shore of Green Bay, five miles S. Ford River. Sec. 1, T. 37 N., R. 24 W. Ford River Twp., Delta Co.
Formation: Yellow sand in dunes in area along Green Bay, depth 4-12 ft. above clay and some places rock. Rock outcropping in places and in some spots sand; is mixed with stone and gravel. Sand has sharp grains, some hard material. Area probably very extensive. Some cuts show sand running as deep as 25-30 ft. Sand around Escanaba is very much deeper and of the same kind as this sample.

Lab. No.: 773, Mich., No. 2045.
Location: One-fourth mile from Soo R. R. and three miles E. of Rapid River, on M 12. Sec. 27, T. 41 N., R. 21 W. Masonville Twp., Delta Co.
Formation: Yellow, sharp, uniform grained sand, a very little bond material, about same as around Escanaba, and sample 2044; depth at least 30-40 ft.; and over 30-40 sq. miles running along shore of Little Bay De Noc Country Pine Barrens. Area extends around St. Jacques and sand seems the same around Big Bay De Noc.

Lab. No.: 774, Mich., No. 2047.
Location: Along Soo R. R., two miles from Lake Michigan and four miles from Engadine, on M 12. Sec. 12, T. 44 N., R. 10 W. Garfield Twp., Mackinac Co.
Formation: Yellow, sharp grained sand, very little bond material, covered by a few inches of white sand. Depth at least 15 ft., probably more. Area about 20 sq. miles.

Lab. No.: 775, Mich., No. 2048.
Location: Three-fourths mile N. Lake Michigan; eight miles from Soo R. R., on M 12. Detour. Sec. 2, T. 42 N., R. 7 W. Hendricks Twp., Mackinac Co.
Formation: Coarse, yellow, sharp grained sand, very little bond, covered with ½ ft. of white sand. Area very extensive from Rexton on the Brevort. Deep.

Lab. No.: 776, Mich., No. 2052.
Location: One and one-half miles N. W. center of Boyne City, on Pine Lake. Sec. 27, T. 33 N., R. 6 W. Evangeline Twp., Charlevoix Co.
Formation: Area of yellow, sharp sand with little bond, extending along Pine Lake and towards Boyne Falls, for 10 sq. miles or more. Depth at least 30-40 ft. Free from stone and gravel in most places.

Lab. No.: 777, Mich., No. 2053. Three miles W. of G. R. & U. R. R., through Elmira. Sec. 6, T. 31 N., R. 5 W. Warner Twp., Antrim Co.
Formation: White, sharp sand, overlaid by ¾ ft. of yellow sand. Area extends around Boyne Falls but not very extensive, seemingly in pockets with clay, gravel and stone. Little bond, 15-20 ft. in depth at least. Sand occurs in ridges through swampy land.

Lab. No.: 778, Mich., No. 2054.
Location: Three-fourths mile N. E. of Simmons and along G. R. & I. R. R. Sec. 4, T. 30 N., R. 5 W. Warner Twp., Antrim Co.
Formation: Yellow, sharp sand, covered by ¾ ft. of brown sand layer which is filled with stone. A few quartzite and gneiss pebbles. Area 1 to 2 townships, extends towards Mancelona, depth 20 ft. or more.

Lab. No.: 779, Mich., No. 2055.
Location: One mile N. limits of Kalkaska and one and one-fourth mile N. G. R. & I. R. R. Sec. 4, T. 27 N., R. 7 W. Kalkaska Twp., Kalkaska County.
Formation: Area of yellow, sharp sand with very little bond, overlaid by ¼ ft. of white sand. A few pebbles of quartzite. Area 20-30 sq. miles around Kalkaska, Crofton and Mayfield, running into gravelly sand towards the S. W. Depth 40 ft. or more over clay in places. Country rolling.

Lab. No.: 780, Mich., No. 2056.
Location: Two miles S. of Sharon, 4 miles S. of Manistee and N. E. R. R. Sec. 8, T. 25 N., R. 6 W. Garfield Twp., Kalkaska Co.
Formation: Fine, gravelly, sharp light yellow sand, very little bond, around Sharon and to the S. W. and N. E. along Manistee River. 30-40 square miles, very deep, country, pine barrens.

Lab. No.: 781, Mich., No. 2060.
Location: On M 11 and one-half mile N. of P. M. R. R. between Gowen and Interlochen. Section 9, T. 26 N., R. 12 W. Green Lake Twp., Grand Traverse Co.
Formation: Light, yellow, sharp sand, with little bond. Covered by 1 to 2 ft. of sand. Depth 20-30 ft. A few pebbles of gneiss, quartzite and limestone. Area seems to cover several square miles between Gowen and Interlochen, and around the small lakes in Western Grand Traverse and Eastern Benzie County.

Lab. No.: 782, Mich., No. 2061.
Location: One mile W. of Honor and one-half mile from Manistee and N. E. R. R., along M 11. Sec. 7, T. 26 N., R. 14 W. Platte Twp., Benzie Co.
Formation: Yellow, sharp sand with little bond, no stone. Area 20-30 square miles around Crystal Lake. Depth, 20-30', probably more, country rolling. Soil changes to clay deposit in places.

Lab. No.: 783, Mich., No. 2063.
Location: Six miles N. E. of Bear Lake and three-quarters mile S. of Arcadia & Betsey River R. R. Sec. 10, T. 24 N., R. 13 W. Pleasanton Twp., Manistee Co.
Formation: Yellow, sharp sand with some bond, possibly over clay. A few quartzite pebbles. Twenty feet deep in some places and probably more in others. Area about 8-10 square miles. Deposit covered 1-2' of brown sand.

Lab. No.: 784, Mich., No. 2065.
Location: One-half mile E. of East Lake and P. M. R. R. Sec. 16, T. 21 N., R. 16 W. Stronach Twp., Manistee County.
Formation: White, gravelly sharp sand, with very little bond. Cut south of East Lake shows 50 ft. depth. Area very extensive; 1 to 2 townships probably of pine barrens.

Lab. No.: 785, Mich., No. 2066.
Location: One mile E. of Ludington on P. M. R. R. Sec. 24, T. 17 N., R. 17 W. Pere Twp., Mason Co.
Formation: Uniform light yellow sharp sand with some bond, depth at least 20-30′ over relatively large area around Ludington. Deposit covered by 1-2″ of yellow sand; no stones. Clay underneath sand in some places.

Lab. No.: 786, Mich., No. 2067.
Location: Along M 20, three-quarters mile N. P. M. R. R., one and one-half miles N. W. of Walhalla. Sec. 17, T. 18 N., R. 15 W. Branch Twp., Mason Co.
Formation: Uniform, light yellow, sharp sand, same as sample 2066. Unknown depth; one cut showed 30′. Area about one and one-half township in Custer, Logan, Eden and Branch townships. Mostly level. Trench.

Lab. No.: 787, Mich., No. 2100.
Location: One and one-half miles S. W. Plymouth and P. M. R. R. Kaiser's place. Sec. 33, T. 1 S., R. 8 E. Plymouth Twp., Wayne County.
Formation: A very variable sandy area, probably running to clay at a depth of from 10-20 ft. in mixture with a little bond. This runs out into gravel and larger stone. The yellow sandy clay mixture seems to run a pocket of a few inches to 1 to 2 ft. in depth and seems to be in relatively small amounts. In one sack is some of the finer gravel screenings from the gravel pit on Kaiser's farm. The area seems to extend N. W. and S. E. through Plymouth for about 6 to 8 square miles. Samples taken from pit.

Lab. No.: 788, Mich., No. 2102.
Location: One-half mile E. of Ann Arbor R. R. and two and one-half miles S. W. of Dundee. Sec. 29, T. 6 S., R. 7 E. Dundee Twp., Monroe County.
Formation.: Sharp sand, no bond; from pit by road. Sand runs very variable from 2-3 ft. deep to a depth of 8-10 ft. A few quartzite and limestone pebbles. Sometimes over clay. Other places over quicksand and gravel. Area seems to extend south towards Lambertville and the state line and covers 30-40 sq. miles. Sample very wet when taken. In places sand is in low dunes; others in low land.

Lab. No. Mich. No. 512.
Location: Two miles N. of D. & M. R. R. Sec. 4, T. 31 N., R. 6 E., Alpena County.
Formation: Rusty yellow sand similar to No. 510. One and one-half miles south and one mile west, plus the lighter colored sand below. This is probably the sand formerly used for molding sand in casting brass.
Grade: Molding sand.

Lab. No.: Mich., No. 514.
Location: Five miles W. of Black River. Sec. T. 28 N., R. 8-9 E. Alcona County.
Formation: Yellow sand, very similar to that on plains, but containing more pebbles. Outcrops where road cuts through top of mounds and is found throughout this district, mixed with moraine and boulder clay.

Lab. No.: Mich. No. 515.
Location: Sec. 2, T. 21 N., R. 5 E, Iosco County.
Formation: Plains sand. Sandy, pebbly clay underlies the plains sand throughout this district in different places. Some smooth clay in other places.

Lab. No.: Mich. No. 517.
Location: Sec. 12, T. 17 N., R. 1 W.; Center Section 16, T. 17 N., R. 1 E. Gladwin County.
Formation: Yellow, rusty sand covered by an inch or two of white sand, and running to clay at about 4 or 5 feet. Seems to possess molding sand possibilities. Samples from pit. Deposit covers 2 or 3 sq. miles.

Lab. No.: Mich. No. 2046.
Location: One-half mile S. E. Cook's Mill and Soo R. R. along M 12. Sec. 3, T. 41 N, R. 17 W. Thompson Twp., Schoolcraft County.
Location: Compact layers of yellow, sharp grained sand, with a little bond material, about the same as around Big Bay de Noc. Large area, depth 15-20 ft., probably more, free from stone. Cliffs 50-60 ft. high east of Manistique show same kind of sand.

Lab. No. Mich. No. 2049.
Location: Three miles E. of Gross Village on Lake Michigan and nine miles from G. R. & I. R. R. at Levering. Sec. 31, T. 38 N., R. 5 W. Bliss Twp.. Emmet County.
Formation: Coarse, yellow sand with very little bond covered with 1-4 ft. of white sand taken from a cut in the road. The layer is 10-20 ft. in depth and extends through 20-30 square miles along Sturgeon and Cecil Bays. In some places there are a few stones. Sample yellow sand.

Lab. No.: Mich., No. 2050.
Location: One and one-quarter miles from center of Pellston and M. 10, and along G. R. & I. R. R. Section 10, T. 26 N., R. 4 W. Maple River Twp., Emmet County.
Formation: Light yellow sand over an area of about 20 sq. miles, sharp grains, very little bond. 30-40 ft. deep at least. The yellow sand is covered by 3-4 ft. of white sand, then 1-2 ft. of compact brown sand. Country mostly plains.

Lab. No.: Mich. No. 2051.
Location: On shore of Little Traverse Bay between Bay View and Petoskey, near G. R. & I. R. R. Sec. 33, T. 35 N, R. 5 W. Little Traverse Twp., Emmet County.
Formation: Light yellow sharp sand, practically no bond, similar to that between Harbor Springs and Petoskey. The Antrim Iron Co. use this sand. Depth where sample was taken 15-20 ft. over limestone, but some cuts show depth of 40-50 ft. Limestone mentioned above used by the North Michigan Lime Co., A. Curtis, Manager, and quarry is about 50 ft. deep of white to blue limestone.

Lab. No.: Mich. No. 2057.
Location: One mile N. of Kingsley and along G. R. & I. R. R. Sec. 33, T. 26 N., R. 10 W. Paradise Twp., Grand Traverse County.
Formation: Light yellow sharp sand, with very little bond, 30-40 ft. deep at least. Area probably 30 sq. miles around Kalkaska and S. W. towards Interlochen. Covered by 1-2 ft. of dark yellow sand. Low hills.

Lab. No.: Mich. No. 2058.
Location: One-half mile N. of Northport; 1¼ miles from G. R. & I. R. R. Section 27, T. 32 N., R. 11 W. Leelanau Twp., Leelanau County.
Formation: Yellow, fine, sharp sand with a little bond covered by 1-2 ft. of brown sand. Depth 30-40 ft. at least, probably more; area 5-6 sq. miles. Seems about the same as around Good Harbor Bay. Low hills. Pit.

Lab. No.: Mich., No. 2059.
Location: One-half mile S. city limits of Grand Traverse and G. R. & I. and P. M. R. R. along M. 11. Section 15, T. 27 N., R. 11 W. Garfield Twp., Grand Traverse County.
Formation: 5-6 sq. miles of gravelly, sharp white sand along shore of Grand Traverse Bay, probably very great depth. Area covered by 1-2 ft. yellow sand. Ridges.

Lab. No.: Mich., No. 2062.
Location: Limits of South Frankfort on A. A. R. R. Dunes. Sec. 34, T. 26 N., R. 16 W. Crystal Lake Twp., Benzie County.
Formation: Beach sand, white, sharp grains, no bond. In dunes around Frankfort. Deep and large area.

Lab. No.: Mich., No. 2068.
Location: Two and one-quarter miles S. of P. M. R. R. along M. 20, Detour. Sec. 3, T. 17 N., R. 14 W. Lake Twp., Lake County.
Formation: Light yellow sand, sharp grains, uniform, very little bond, seemingly very deep. Extends through Baldwin and 2-3 miles east.

Lab. No.: Mich., No. 2069.

Lab. No.: Mich., No. 2070.
Location: Along M 24, ¼ mile from Field Station on P. M. R. R. Section 14, T. 14, N., R. 12 W. Wilcox Twp., Newaygo County.
Formation: Light yellow, uniform sharp sand in low dunes, very little bond covering about 1 sq. mile. Country to the east seems to be sand over clay, low and wet.

Lab. No. Mich., No. 2075.
Location: Three miles N. Belding on M. 66; 3 miles from P. M. R. R. Sec. 34, T. 9 N., R. 8 W. Eureka twp., Montcalm County.
Formation: Light, yellow, sharp, uniform sand, with few stones and little bond covered by 1-2 ft. of dark yellow sand. Area extends from Belding towards Greenville for 1-2 townships. Depth at least 30-40 ft. in dunes.

Lab. No.: Mich., No. 2076.
Location: Two miles W. of Mecosta on M. 24, ½ miles S. P. M. R. R. Sec. 9, T. 14 N., R. 8 W. Morton Twp., Mecosta County.
Formation: Yellow, sharp sand, with little bond mixed with some stone. 30 ft. deep at least in places. Layer of gravel 2-3 ft. deep over top of deposit. Area runs into gravel and stone in places, covers 1-2 townships. Pine barrens.

Lab. No.: Mich., 2071.
Location: Along M 11 and P. M. R. R. 2½ miles N. of Montague. Sec. 4, T. 12 N., R. 17 W. Montague Twp., Muskegon Co.
Formation: Uniform, yellow sharp sand with very little bond; few stones in places, covering a very large area over the larger part of Muskegon County. Country mostly level pine barrens.

Lab. No.: Mich., No. 2072.
Location: Two and seven-tenths miles W. of Nunica on M 16 and ¼ mile S. of G. R. G. H. & M. R. R. Sec. 21, T. 8 N., R. 15 W. Crockery Twp., Ottawa Co.
Formation: Light, yellow sharp sand with very little bond. No stones. In dunes to a varying depth from a few feet to 30 or more, overlying clay in places. Area extends into Muskegon County.

Lab. No.: Mich., No. 2073.
Location: One-half mile W. of P. M. R. R. and 1 mile S. of Mona Lake; 2½ miles S. of Muskegon Heights. Sec. 17, T. 9 N., R. 16 W. Norton Twp., Muskegon Co.
Formation: Light, yellow, sharp sand covered by darker yellow sand about the same as sample. No. 2072. Looks very deep, covering greater part of Muskegon Co. Very little bond. Country level—pine barrens.

Lab. No.: Mich, No. 2074.
Location: Along M 11 and P. M. R. R. 1.8 mile from Agnew. Sec. 36, T. 7 N., R. 16 W. Grand Haven, Ottawa Co.
Formation: Light yellow, sharp sand without bond in low dunes through the country between Grand Haven and Holland. Large area.

Lab. No.: Mich., No. 2077.
Location: One-half mile S. of limits of Newago and ¾ mile E. P. M. R. R. Sec. 31, T. 11 N., R. 12 W. Brooks Twp., Newago Co.
Formation: Light, yellow, sharp uniform sand with little bond. Area covers two townships extending N. and E. from White Cloud to Newago. Dunes of variable height. Deposit between the dunes. North of Newago sand is mixed with clay within short distances.

Lab. No.: Mich., No. 2078.
Location: Two miles N. W. of P. M. R. R. and Holton, on M 24. Sec. 11, T. 12 N., R. 15 W. Holton Twp., Muskegon Co.
Formation: Large area of light yellow, sharp uniform sand, little bond, no stones, covered by 1-2′ of darker yellow sand. Depth very great, area most of Muskegon County. Area extends west into Blue Lake Township. Country pine barrens. Some gravel bluffs in places.

Lab. No.: Mich., No. 2079.
Location: Three miles N. W. of Hart and P. M. R. R. on M. 11, Detour. Sec. 6, T. 18 N., R. 15 W. Weare Twp., Oceana Co.
Formation: Hills of light yellow, sharp sand mixed with gravel in places. Area extends east of Pentwater for 10 sq. miles. Some bond, depth at least 30 feet. Running into clay in places.

Lab. No.: Mich., No. 2080.
Location: Eastern edge of town on G. T. R. R. span. N. W. ¼ Sec. 28, T. 7 N., R. 11 W. Grand Rapids Twp., Kent Co.
Producer: Grand Rapids Clay & Products Co.
Formation: White, sharp sand with some bond, underneath 30′ clay deposit, seems to be uniform and great depth. Some stone in places, others free from stone, 40 or more acres all told.

Lab. No.: Mich., No. 2081.
Location: On M 65, 4 miles S. of Brighton and 3 miles N. E. G. T. R. R., 3 miles S. P. M. R. R. Sec. 20, T. 1 N., R. 6 E. Green Oak Twp., Livingston Co.
Formation: Fine, sharp, light yellow sand with some bond. Soil very variable, going to clay and gravel in places. In Sec. 29, gravel pits show depth of 75-100′. Sand full of stone and hard to tell extent of the area. Probably not very large.

Lab. No.: Mich., No. 2082.
Location: Along M 65, 1 mile N. of Brighton and P. M. R. R. Sec. 19, T. 2 N., R. 6 E. Brighton Twp., Livingston Co.
Formation: Fine light yellow, sharp, uniform sand with very little bond, changing rapidly to gravel in places. Deposit lies in dunes running N. E. and S. W. Deposit samples seemed at least 30′ deep from cut in the road. Area probably several square miles.

Lab. No.: Mich., No. 2083.
Location: Five miles E. G. T. R. R. on gravel road. Sec. 5, 6, T. 8 N., R. 6 E. Mt. Morris Twp., Genessee Co.
Formation: Fine, sharp, light yellow sand with some bond, uniform 20-25 ft. deep at least, in places running to clay. Area runs into Taymouth and Montrose townships. Same stuff in Taymouth, T. 9 N., R. 6 E., Sec. 16, 17.

Lab. No.: Mich., No. 2084.
Location: Three and one-half miles W. of Saginaw, 1 mile W. of P. M. R. R. Not very large area. Sec. 8, T. 12 N., R. 4 E. Saginaw Twp., Saginaw Co.
Producer: Saginaw Products Co.
Formation: Light yellow sharp sand 8-10′ deep, over three-fourths inch, mixed with layers of darker yellow sand used in making sand lime brick. Company reports coarser sand taken from pits in Thomaston Township. T. 12 N., R. 3 E., Sec. 7.

Lab. No.: Mich., No. 2086.
Location: Two miles W. Amadore and P. M. R. R. Sec. 29, T. 16 E., R. 9 N. Sanilac Co.
Formation: Fine, sharp white to yellow sand, free from stone, little bond, 20 feet deep with a 10 ft. layer of yellow sand above, pockets of gravel in some places; underneath the sand is a layer

of clear gravel running into clay in places. Area is a mixture of sand, gravel and clay. Cut shows strata for a depth of more than 40 feet. Sample white sand.

Lab. No.: Mich., No. 2087.
Location: Two miles N. of Amadore on M 29, Bob Flynn place on P. M. R. R. Sec. 17, T. 9 N., R. 16 E. Worth Twp., Sanilac Co.
Formation: Dunes of yellow, sharp, fine grained sand with a little bond. Uniform, covered by a few feet of brown sand. Small area covering a few acres.

Lab. No.: Mich., No. 2088.
Location: Sec. 13, T. 6 N., R. 16 E., and Sec. 8, T. 6 N., R. 17 E. Kimball Twp., St. Clair Co.
Producer: Reynolds & Bailey Sand Co. Connors & Trulippe Co.
Formation: Supply core sand, employ 6-7 men and 3 teams. Plant has operated for 5-6 years. Supplies Holmes Foundry in Port Huron and also other foundries. Ship 6-10 cars per day. Connors & Trulippe Sand Co. ship two cars per day. Sand is yellow, rather fine grained, sharp, little bond, covered by a foot or two of brown sand. Very great depth.

Lab. No.: Mich., No. 2089.
Location: Along Tekonsha road to Burlington, on M. C. R. R. along St. Joseph River. Sec. 29, T. 4 S., R. 6 W. Tekonsha Twp., Calhoun Co.
Formation: Stony, gravelly, yellow, sharp sand with little bond in dunes 30′ or more in height. A great deal of this kind of sand along the road from Marshall to Tekonsha. Area 10-12 sq. miles. Some places gravel pits.

Lab. No.: Mich., No. 2090.
Location: Near M. C. R. R. 1½ miles N. W. Athens. Sec. 21, T. 4 S., R. 8 W. Athens Twp., Calhoun Co.
Formation: Gravelly, sharp sand, full of stone to depth of 30′ at least. Lies in low ridges. No bond.

Lab. No.: Mich., No. 2091.
Location: On M 17, 2 miles W. of Matawan and M. C. R. R. Sec. 15, T. 3 S., R. 13 W. Antwerp Twp., Van Buren Co.
Formation: Coarse, yellow, sharp sand, with a little bond. Probably over clay, stony and gravelly in places. 10-15′ deep, large area between Paw Paw and Kalamazoo. Dunes, variable soil.

Lab. No.: Mich., No. 2092.
Location: One mile W. of Plainwell and P. M. R. R. Sec. 25, T. 1 N., R. 11 W. Gun Plain Twp., Allegan Co.
Formation: Coarse, sharp, yellow sand with a little bond. Great depth. Some places free from stone, others very gravelly and stony. Mr. Stamp has a sand pit at Plainwell used locally for building. Country mostly level with low dunes in some places.

Lab. No.: Mich., No. 2093.
Location: Five miles N. of Kalamazoo, on M 17 and 2 miles W. of G. R. & I. R. R. Dunes. Sec. 28, 29, T. 1 S., R. 11 W. Cooper Twp., Kalamazoo Co.

Formation: Gravelly, sharp, yellow sand full of larger stones in some places. Area extends around Kalamazoo for 5-6 sq. miles. Depth at least 25'.

Lab. No.: Mich., No. 2094.
Location: One and one-half miles E. of Augusta on M 17 and M. C. R. R. from cut in road. Sec. 26, T. 1 S., R. 9 W. Ross Twp., Kalamazoo Co.
Formation: Light yellow, gravelly sharp sand, 20-25' deep and very full of stone in some places. Large area of few square miles between Kalamazoo and Augusta towards Battle Creek. In low dunes mostly.

Lab. No.: Mich., No. 2096.
Location: Four miles from Chicago, Kalamazoo & Saginaw R. R. on M 37 and Cedar Creek. Sec. 9, T. 2 N., R. 8 W. Baltimore Twp., Barry Co.
Formation: Fine, light yellow sand, some bond, from cut 30-40' deep. In places sand is full of stone, in others it seems free from stone. Area covers 5-6 sq. miles probably. Covered by 3-4' of sandy gravel.

Lab. No.: Mich., No. 2097.
Location: One mile N. of Alto on M. 37. Sec. 32, T. 9 N., R. 6 W. Lowell Twp., Kent Co.
Formation: Fine, sharp, yellow, uniform sand in low dunes, covered by 1-6' of gravelly sand. No stones, little bond, depth 25' or more. Seemingly relatively large area stretching through McCords.

Lab. No.: Mich., No. 2098.
Location: Sandpit N. of Grand Rapids City Limits, sand used for road. Sec. 14, T. 1 N., R. 12 W. Walker Twp., Kent Co.
Formation; Sample of light yellow, uniform, sharp sand with very little bond, few stones, lying in dunes. High dunes, over one sq. mile, clay between dunes.

Lab. No.: Mich., No. 2099.
Location: On M 13. ten miles S. of Grand Rapids. and on Interurban R. R. Sec. 12, T. 5 N., R. 12 W. Byron Twp., Kent Co.
Formation: Dunes of light yellow, uniform, sharp lake sand with no bond. Sand changes to gravel and clay in places. Seemingly sand runs to great depth. Area covers five or more square miles.

Lab. No.: Mich., No. 3000.
Location: Two miles S. W. Allegan and P. M. R. R. Hale's Place. Sec. 32, T. 2 N., R. 13 W. Allegan Twp., Allegan Co.
Formation: C. W. Young foundry, Allegan has used local molding sand for years; deposit now exhausted. Hale opened up his pit this year and his sand is very fine, smooth, clay sand mixture covering 100 acres or more, depth 1-5'. Gets it out by truck at present.
Grade: Molding sand.

Lab. No.: Mich., No. 3001.
Location: One and one-half miles E. of Pullman and P. M. R. R. Sec. 10, T. 1 N., R. 15 W. Lee Twp., Allegan Co.

Formation: Light, yellow, coarse, sharp, uniform sand; very little bond, stony in places, depth at least 20'. Pine plains with dunes of lake sand in places. Large area stretching north of Fennville and Bravo.

Lab. No.: Mich., No. 3002.
Location: Five miles W. of Pullman and P. M. R. R. Sec. 10, T. 1 N., R. 16 W. Casco Twp., Allegan Co.
Formation: Yellow sand, clay mixture, fine, smooth, clay bond, 10-15' deep over seemingly quite large area one-half mile square at least. Country rolling.

Lab. No.: Mich., No. 3004.
Location: Along M 11, six miles N. of Saugatuck, one mile E. G. R. & Muskegon R. R. Sec. 13, T. 4 N., R. 16 W. Laketon Twp., Allegan Co.
Formation: White, sharp dune sand, no bond, probably great depth; extends along Lake Michigan shore, making dunes in places all the way from Holland to Saugatuck.

Lab. No.: Mich., No. 3005.
Location: Along M 17, three miles E. of Hartford and R. R. Sec. 12, 13, T. 35 S., R. 16 W. Hartford Twp., Van Buren Co.

Lab. No.: Mich., No. 3006.
Location: One mile N. W. of Berlamont and near M. C. R. R. Sec. 11, T. 1 S., R. 15 W. Columbia Twp., Van Buren Co.
Formation: Clay sand mixture, fine gravel, smooth, variable soil changing to sand, gravel and clay in a short space. Area hard to ascertain; depth 7-10' in places. Low hills. Sample clay and sand mixture.

Lab. No.: Mich., No. 3007.
Location: Two miles E. of Lacota on M. C. R. R. Sec. 6, T. 1 S., R. 15 W. Columbia Twp., Van Buren Co.
Formation: Dune sand, light yellow, sharp, uniform, no bond, seemingly great depth, area seems to extend over two townships east and south of South Haven. Low dunes.

Lab. No.: Mich., No. 3008.
Location: One-half mile S. of Burnips, six miles W. of Lake Shore & Mich. Southern R. R. Sec. 14, T. 4 N., R. 12 W. Salem Twp., Allegan Co.
Formation: Yellow and white sharp sand mixture to a depth of 10-12' over clay in places. Some bond. Very variable soil. Area hard to ascertain.

Lab. No.: Mich., No. 3009.
Location: One mile E. of Middleville & M. C. R. R. Sec. 25, T. 4 N., R. 10 W. Thornapple Twp., Barry Co.
Formation: Stony, reddish, yellow clay sand mixture 15-25' deep in places at least. Clay runs in streaks over yellow sand. Soil variable. Area extends towards Hastings, probably 3-4 sq. miles.

Lab. No.: Mich., No. 3010.
Location: Four and one-half miles W. of Hastings on M 79; three-fourths mile S. of Morgan and M. C. R. R. Sec. 30, T. 3 N., R. 7 W. Castleton Twp., Barry Co.
Formation: Coarse, sharp, yellow sand with little bond from cut in M 79, 35-40′ deep, runs into gravel in places. Deposit full of stones, sand lies in dunes. Area hard to ascertain, as soil is variable. Gravel pits in places throughout this locality.

Lab. No.: Mich., No. 3011.
Location: One mile E. of Ceresco, on M. 17, near M. C. R. R. Sec. 30, T. 25 N., R. 6 W. Marshall Twp., Calhoun Co.
Formation: Sharp, coarse sand from 20′ cut, mixed with stone and layers of gravel in some places. Gravel pits in some parts of this locality. Area extends from Marshall to Battle Creek.

Lab. No.: Mich., No. 3012.
Location: One mile N. of M 17 and Urbandale and the M. C. R. R. Sec. 22, T. 1 S., R. 8 W. Bedford Twp., Calhoun Co.
Formation: Fine grained brown sand, clay bond, filled with stone and gravel in ridges covered by 1-4′ of coarse sand. Sand mixture is 10-12′ deep in places. Too stony to be of much value.

Lab. No.: Mich., No. 3013.
Location: Three miles S. E. of Albion and one-half mile S. of M. C. R. R., on Albion Concord Road. Sec. 8, T. 3 S., R. 3 W. Concord Twp., Jackson Co.
Formation: Sharp, light yellow sand, mostly without bond, some places streaked with a little clay, gravel and stone, low dunes, probably over clay at a depth of 20-25′ or more.

Lab. No.: Mich., No. 3014.
Location: Along M 17, one mile E. of Jackson city limits and M. C. R. R. Sec. 31, T. 2 S., R. 1 E. Leoni Twp., Jackson Co.
Formation: Along M. 17, one mile east of Jackson city limits and M. C. R. R. Six feet of light yellow coarse sand over fine grained, stony gravelly sand with some clay bond. Very variable soil, but area seems to extend around east of Jackson for a few square miles. Gravel pits in some places in this area. Seems to be too stony for use.

Lab. No.: Mich., No. 3015.
Location: Two miles W. of Chelsea, on M 17, and one mile S. of M. C. R. R. Sec. 22, T. 25 S., R. 3 E., Sylvan Twp., Washtenaw Co.
Formation: Coarse, sharp, yellow sand in hills at least 30-40′ deep, covered by a few feet of gravelly sand with pockets of gravel and stone in places. Area extends over 6-8 square miles between Chelsea and Grass Lake.

Lab. No.: Mich., No. 3016.
Location: Three miles N. of Marshall and M. C. R. R. Sec. 12, T. 2 S., R. 6 W. Marshall Twp., Calhoun Co.
Formation: Sharp, yellow sand and streaked with brown. Mixed with streaks of clay and stone in places. 100 acres or more in deposit; depth at least 25′ in low hills. Mr. Adams, of Flint Foundry Co., in Marshall, has used this sand for core sand when

mixed with oil. Says there is more of the same kind of sand on the Jewett farm, one and one-half miles S. W. of Marshall.

Lab. No.: Mich., No. 3017.
Location: Three miles S. E. Jackson, one-half mile W. Lake Shore R. R. Sec. 18, T. 3 S., R. 1 E. Napoleon Twp., Jackson Co.
Formation: White, coarse sand, streaked with brown sand, covered with 1-2′ of brown, stony sand, very little bond. Deposit lies in low hills. Runs to gravel in places. Area 1-2 townships south and east of Jackson. Gravel pits in places.

Lab. No. Mich., No. 3018.
Location: Three miles S. E. Norwell and Lake Shore R. R. Sec. 12, T. 4 S., R. 2 E. Jackson Co.
Formation: Stony, gravelly sand in hills, depth probably 50′ or more; changes to yellow, stony clay in places. Very little bond area, 2-3 townships each of Jackson.

North Carolina

Lab. No.: 1.
Location: Chapel Hill, N. C.
Producer: Dr. Geo. D. Vick, Selma, N. C.
Formation: Occurs as a terrace on the bank of Neuse River just above low water. Deposit has overburden of 2 ft. sand; is 12 ft. thick.

Lab. No.: 2.
Location: From Chapel Hill, N. C.
Producer: W. A. Green, Selma, N. C.
Formation: Occurs on the upper-most of three terraces on the east side of Neuse River. Deposit has overburden of 1 to 2 ft. of soil, etc. Thickness of sand 2 to 3 ft. and covers 100 acres more or less. The pits lie along side of railroad and sand is loaded by hand.
Grade: The sand has been used for cores and coarse castings. Small business well established.

Lab. No.: 3.
Location: From Chapel Hill, N. C.
Producer: Robert Fenner, Halifax, N. C.
Formation: Sand occurs as stream terrace or filling near a small creek. Deposit has overburden of 1½ to 2 ft. of soil loam. Sand about 4 ft. thick. Extent, unknown.

Lab. No.: 4.
Location: From Chapel Hill, N. C.
Producer: Eureka Lumber Co., Washington, N. C.
Formation: Deposits are found in the outskirts of Washington along river. Overburden of 2 or 3 ft. of soil. Sand 3 to 4 ft. thick. Area not known.
Grade: Molding.

Lab. No.: 5.
Location: Joe Patrick Estate, Washington, N. C.
Formation: May belong to Chowan formation. Sand bank is 2 miles S. of Washington. Clay overburden 2 to 5 ft. Sand 5 to 7 ft. thick. Indications are that there is a large deposit. Sand overlies Miocene marl.
Grade: Small amounts were formerly used by local foundry.

Lab. No.: 6.
Location: Washington, N. C.
Producer: W. M. Orr.
Formation: Probably occurs in Chowan formation. Deposits lie along Atlantic Coast Line Railway, 3 miles S. of Washington. Has an overburden of 2 to 4 ft. of clay. Four to 7 ft. of sand. Very uniform as seen in the bank. Apparently large deposit.

Lab. No.: 7.
Location: One mile west of Pinetown.
Producer: Property of Norfolk Southern Ry.
Formation: Chowan. Twelve to 18 inches of soil overburden and 2 to 4 ft. of sand. Area unknown. Sand grades into clay below.
Grade: Formerly used in foundry at Pinetown. Not worked at present.

Lab. No.: 8.
Location: Sand on Pender Creek 4 miles N. of Washington.
Producer: Tyre Tranner, Washington, N. C.
Formation: Pamlico. Overburden of 3 to 5 ft. of soil and sand, 4 to 6 ft. of fairly uniform sand.

Lab. No.: 9.
Location: Sand found at Wharton Station on A. C. L. Ry., 7 miles west of Washington.
Producer: W. M. Orr, Washington, N. C.
Formation: Pamlico. Two to 4 ft. of overburden. Sand 3 to 4 ft. thick. In places irregular. Size of deposit unknown.

Lab. No.: 10.
Location: Farmville, N. C.
Producer: W. P. Taylor.
Formation: Overburden of 1 to 2 ft. of soil and loam. Three to 4 ft. of sand. Area unknown. Discovered while looking for concrete sand.

Lab. No.: 11.
Location: Pinetops, N. C.
Producer: East Carolina R. R.
Formation: Wicomico. Pits were opened for ballast and have reached a depth of 15 ft. in places. About 3 ft. from the surface is a layer of sand 3-5 ft. thick, irregular in places, which has some indication of molding sand, but never worked as such.

Lab. No.: 12.
Location: Rocky Mount, N. C. Town property on Tar River, 1 mile N. of city.
Formation: Occurs as a terrace along the river. An overburden of 18 inches of soil, with 2 to 6 ft. of sand below. Supposed to

have been worked on larger scale at one time.
Grade: Used in local foundry in Rocky Mount.

Lab. No.: 13.
Location: Goldsboro, N. C. Sands along river flats where Little River enters Neuse River.
Producer: H. Weil & Bro.
Formation: Wicomico. Sand occurs in irregular lenses 1 to 2 ft. thick, often overlain by clay.
Grade: Has been extensively used in local foundries and proves very satisfactory.

Lab. No.: 14.
Location: Kinston, N. C. Sand is seen in cut of the A. C. L. Ry., one mile north of town.
Producer: E. V. Webb.
Formation: Chowan. Overburden of 2 to 4 ft. of clay. Sand is 4 to 6 ft. thick. Is exposed for 300 ft. in railroad cut. (See Note No. 15.)
Grade: Has been used in local foundry and found satisfactory. Not worked at present.

Lab. No.: 15.
Location: Kinston, N. C. Pits one mile east of Kinston.
Producer: William Hays.
Formation: Chowan. Sand 4 to 10 ft. thick. Outcrop for 200 to 300 ft. along slope of hill. Overburden of 2 ft. to 4 ft. Note for Nos. 14 and 15.—About one mile from Kinston from S. E. to N. W., a sort of semi-circle of hills is seen around the town. It is in connection with these hills that possible molding sands were found. If the sands are of value, there can be doubtless a large supply obtained from these hills.
Grade: Used in local foundry and gives very good results.

Lab. No.: 16.
Location: North Carolina. Deposits two miles north of Granger, along railroad and highway cuts.
Producer: Henry Canady.
Formation: Chowan. Overburden 2 to 3 ft. thick with 2 to 6 ft. of sand below. Outcrops 300 ft. along highway cut. Sand slightly irregular.

Lab. No.: 17.
Location: Kinston, N. C.
Producer: Bob Dunn.
Formation: Sand is seen about 2 miles N. E. of Kinston along cuts by roadside. Chowan formation. A coarse sand varying up to 6 ft. and greater in depth.

Lab. No.: 18.
Location: Kinston, N. C. One mile north of Kinston, along highway.
Producer: Albert Turner.
Formation: Chowan. Overburden of about 2 ft. Sand 4 ft. or greater in thickness. Exposed for 300 or 400 ft. in width along road.

Lab. No.: 19.
Location: Newbern, N. C. Sand on Brice Creek, 4 miles S. W. of Newbern.
Producers: John Dunn and H. R. Bryant.
Formation: Pamlico. One and one-half to 2 ft. of overburden with 2 to 4 ft. sand below. Area unknown. Sand occurs in irregular lenses.
Grade: Used in local foundry, but not very satisfactory.

Lab. No.: 20.
Location: Sand at East Wilmington Station, near Wilmington.
Producer: Property of Atlantic Coast Line Railroad.
Formation: Occurs along both sides of railroad in a cut several hundred ft. long. Two to 3 ft. of overburden and 2 to 4 ft. of sand below, grading into clay.
Grade: Formerly used in local foundry. Not worked at present.

Lab. No.: 21.
Location: Leland, N. C.
Producer: J. J. Knox.
Formation: Sand deposits at El Paso Station on the Wilmington, Brunswick & Southport Railroad. About one ft. of overburden. Two to 3 ft. of uniform sand. Outcrops 400 ft. along railroad cut.

Lab. No.: 22.
Location: Town Creek, N. C. Sand is found on point of hill near bridge across Town Creek at Lindsey Walker's store.
Producer: Lindsey Walker.
Formation: Two to 3 ft. of overburden. Three to (?) ft. of sand. Outcrop seen for 300 ft. along road cut.

Lab. No.: 23.
Location: Wilmington, N. C. Pits on outskirts of Wilmington.
Producer: T. G. Empey.
Formation: Probably molding sand was discovered while digging filler sand. Molding sand is irregular. Two to 6 ft. of overburden, with 2 to 4 ft. of sand, with clay bond.
Grade: Pits worked for filler sand. Molding sand not worked.

Lab. No.: 24.
Location: Deposits two miles N. W. of city.
Producer: City of Fayetteville, N. C.
Formation: Overburden never over 2 ft.; sand from 6 in. to 6 ft. thick. Size of deposit not determined.
Grade: Sand is being used by local foundry for plow casting.

Lab. No.: 25.
Location: Fayetteville, N. C. Sand three miles S. W. of Fayetteville, on Branson Creek, at Clark's Pond.
Producer: J. B. Clark.
Formation: Overburden, light. Sand varies from 4 to 10 ft. in thickness and apparently covers several hundred acres.
Grade: Has been successfully used in local foundry in Fayetteville. Has never been worked commercially.

Lab. No. 26.
Location: Gibson, N. C. Pits two miles W. of Gibson, on Seaboard Air Line Railway.
Producer: Mr. Doster.
Formation: In pits molding sand found. Overburden up to 10 ft. thick. Amount of molding sand not known, but indications are that there is abundance. Not worked for molding sand.
Grade: Pits have been worked for concrete and filler sand, but not for molding sand.

Lab. No.: 27.
Location: Lillington, N. C.
Producer: Standard Sand & Gravel Co.
Formation: This is not a natural sand, but consists of washings from a big sand and gravel plant. Quality of sand is determined by control of discharge from washing plant. If valuable, supply is great, as company owns about 1,000 acres of sand and gravel deposits varying in depth up to 40 ft. This molding sand idea is an experiment.
Grade: Washings from sand and gravel plant. Molding sand idea is an experiment.

Lab. No.: 28.
Location: Catawba River Sand Co. Mt. Holly, N. C.
Producer: F. H. Dunn.
Formation: Sand occurs at a terrace about 200 ft. wide along west side of Catawba River. Sand 2 to 6 ft. thick with scarcely any overburden.

Lab. No.: 29.
Location: Mt. Holly, N. C.
Producer: J. W. Welsh.
Formation: This sand is a terrace along the W. side of the Catawba River and is a continuation of the sand described in No. 28. Two hundred ft. wide, 4 to 6 ft. deep. Length unknown. Little or no overburden.

Lab. No.: 30.
Location: Sand pits just N. of Mt. Holly, and near the Seaboard Air Line Ry., near mouth of Dutchman Creek.
Producer: Mrs. P. E. Lentze, Mt. Holly, N. C.
Formation: About 2 ft. of overburden, 4 or 5 ft. of sand covering several acres.
Grade: Sand has been used in Norfolk, Va., Wilmington, N. C., for coarse castings.

Lab. No.: 31.
Location: Sand ten miles above Lenoir on road to Blowing Rock.
Producer: J. H. P. Cilly, Hickory, N. C.
Formation: Occurs as a residual concentration in stream valley near Yadkin River.
Grade: Not worked commercially, but was tried in local foundry and found satisfactory.

Lab. No.: 32.
Location: Sand is three miles W. of Hickory on Southern R. R.
Producer: W. B. Council, Hickory, N. C.

Formation: Overburden not more than 1 ft. thick. Sand 1 to 2 ft. thick. Covers 40 to 50 acres. Sand apparently is partly residual and partly transported.
Grade: Has been used in local foundry at Bailey Ave.; found very satisfactory.

Lab. No.: 33.
Location: Sand one mile E. of Hickory.
Producer: John Mouser, Hickory, N. C.
Formation: Little or no overburden. Sand 1 or 2 ft. thick. Area not known.
Grade: Being used in local foundry in Hickory; a satisfactory sand.

Lab. No.: 34.
Location: Three miles W. of Hickory on Catawba River.
Producer: Property of Southern Power Co.
Formation: Occurs as a terrace along the south bank of the river 200 or 300 ft. wide, 5 to 6 ft. deep and of unknown length.
Grade: A fine sand used in Hickory for casting school desk frames.

Lab. No.: 35.
Location: From terrace along N. side of Catawba River.
Producer: Frank W. Eliot, Catawba, N. C.
Formation: If any good as molding sand, supply is large. Associated with the sands worked are large bodies of clayey material, that resemble molding sand.

Lab. No.: 36.
Location.: Sand on N. side of Catawba River, two miles E. of Catawba station.
Producer: Statesville Brick Co., Statesville, N. C.
Formation: Sand occurs as a terrace 400 to 500 ft. wide, depth 4 to 10 ft. Sand apparently uniform throughout. Sand has been sold as a filler, but not for molding sand.

Lab. No.: 37.
Location: Sand is found on farm about one mile E. of Statesville.
Producer: H. R. Cowles, Statesville, N. C.
Formation: Little or no overburden. Sand is about one ft. thick. Apparently covers farm of 75 acres.
Grade: Sand is used in foundry at Gastonia. Shipments made two or three times a year.

Lab. No.: 38.
Location: One mile E. of Statesville.
Producer: H. R. Cowles, Statesville, N. C.
Formation: This is a part of the same sand described in No. 37; covers 30 or 40 acres. Little or no overburden. One ft. thick. Same as No. 37, except coarser.

Lab. No.: 39.
Location: Sand is found on Third Creek, two miles S. of Statesville.
Producer: W. T. Barnhardt, Statesville, N. C., Route 1.
Formation: Occurs in alluvial terrace on north side of creek. About 6 inches of overburden. Sand 2 to 3 ft. thick. Area unknown.
Grade: Used in local foundry at Statesville and some has been shipped.

Lab. No.: 45a.
Location: From along coast.
Formation: Dune sand of great extent.

Lab. No.: 46a.
Location: Dune sand from along coast.

Lab. No.: 319.
Location: Selma, N. C. Sample taken at N. & W. Ry. shops at Roanoke, Va.
Grade: Used for iron casting.

New Jersey

Lab. No.: 229.
Location: Millville.
Producers: Whitehead Bros. Co.
Formation: Bridgeton (Pleistocene). A few quartz pebbles ¼ inch diameter. On 70, 100 140 and 200 a few mica flakes.
Grade: Millville gravel No. 6.

Lab. No.: 230.
Location: Lumberton.
Producer: J. W. Paxson Company pit.
Formation: No pebbles. On 70 to 270, inclusive, have a few mica flakes.
Grade: Coarse Lumberton.

Lab. No.: 501.
Location: Near Millville, Cumberland County, N. J., W. of Maurice River, from 1¼ to 1¾ miles S. of R. R. station at Millville.
Producer: G. F. Pettinos. Office, screening plant and loading wharf are 1⅝ miles due S. of R. R. station.
Formation: Bridgeton (Pleistocene) marine. About 13 per cent of pebbles mainly quartz and quartzite, about ⅓ inch diameter.
Grade: Coarse molding gravel.
Notes: Location: Southerly pit of this group. About ⅜ mile S. W. of office. Transportation: By auto truck to screening and mixing plant near the office. Dimensions: Large acreage. Circular pit, has been worked for several years. Working face at least 1,000 feet. Portion now being worked over 100 feet. Structure, etc.: Nearly horizontal stratified deposit. Rather uniform in character along the working face. Overburden: About 3 feet thick; chiefly loose gray sand; removed by steam shovel. Working face. From 10 to 12 feet high, dominantly dark brown in color near the top, more yellowish brown below. Central portion of section persistently cross bedded; highly variable grain size in the cross bedding; numerous iron oxide dividing strips. For a foot or more down from the top there is considerable iron oxide in the material, and this portion is very firmly compacted and difficult to dig through. There is no well defined coarse gravel layer here such as sometimes occurs near the top of the Bridge-

ton; but there is a great deal of fine gravel, pebbles ranging from 1/32 to 1/4 inch, with occasional larger ones (that are screened out at the screening plant). There is some fine material, but relatively little compared with some other pits. The total amount of bond is also relatively small here. The Superintendent called this material his "coarse molding gravel with very little bond," and said they mix it with material from their northerly pit in the Bridgeton formation to supply more bond and more fine materials. Method of Working: As a bank, by steam shovel. Method of Taking Sample. From face of bank, 10 inch strip, for 6 feet down from the top, supplemented by material fallen from steam shove at foot of bank, and which concealed lower part of face at this point). Pile mixed and quartered. Includes some coarse material which would have been screened out by shipper (i. e., over ¼ in. mesh).

Lab. No.: 502.

Location: Near Millville, Cumberland County, N. J., W. of Maurice River, from 1¼ to 1¾ miles S. of R. R. station at Millville.

Producer: G. F. Pettinos.

Formation: Cohansey (Pliocene). A few pebbles, chiefly quartzite, about ⅓ inch diameter.

Grade: Sharp silica steel molding sand.

Notes: Cut from bank in westerly pits. Location: Western pit and largest one of this group. About ⅜ mile W. of office. Transportation: Steam locomotives and small cars to loading wharf. Dimensions: Large acreage. Large circular pit, has been worked several years. Working face over 1,500 feet around. Portion now worked about 200 feet long. Looks as though it might have been a hill, originally. Structure: Nearly horizontal stratified deposit. Quite uniform in general character along the face. Overburden: About 6 feet. Not examined. Stripped well back, by steam shovel. Working Face: From 30 to 40 feet high. Where they were working at the time of visit, the bank was nearly all sand, with distinct horizontal stratification, and dominatly fine in grain. The freshly exposed surface varied in color from place to place. One area near the base of the bank, about 3 feet high by 6 feet broad, was nearly white, like glass sand. Nearby laterally and at higher levels, the sand was chiefly light yellow with patches or streaks of orange and reddish color. A few clay streaks occur, one about 10 inches thick being seen which they remove separately and discard. Some thin pebble bonds. The material has poor bond. The whole bank is worked as the steam shovel moves along. The Superintendent called this his "sharp silica steel molding sand," and said much of it goes to Chester, Pa., and Lynn., Mass., for use as a steel molding sand. The material is sometimes used in mixture by manufacturers who add more bond to it. Method of Taking Sample: Pile made by taking shovelfuls from various spots and then quartered. Transportation: Water transportation down Maurice River to Delaware Bay, thence to Philadelphia, or elsewhere. Rail transportation from Millville to Camden and Philadelphia. Large fleet of small auto trucks hauling from pits to screening plant, loading wharf, and to railroad at Millville. Steam locomotives and cars hauling from some pits to wharf. Operate own barges on the river.

Lab. No.: 503.
Location: Near Millville, Cumberland County, N. J., W. of Maurice River, from 1¼ to 1¾ miles S. of R. R. station at Millville.
Producer: G. F. Pettinos, operator.
Grade: Molding gravel with strong bond.
Notes: Sample taken from stock pile beneath mixer and screen. Taken by shovel from a dozen points on the pile. Not quartered. Includes material from pit where sample 501 was taken and material from northwest pit in Bridgeton formation about ⅜ to ½ mile northwest of office. The Superintendent said that the Baldwin Locomotive Works use a mixture of about 80% of the material like N. J. 501 and 20% of the finer material with more bond obtained from the northwest pit just referred to. This northwest pit was visited by the collectors, but no sample was taken. The material was very similar in general appearance to the upper portion of the pit from which sample 501 was taken; but contained more bond between both the gravel and the sand, the bond being both of the iron oxide and clay types. Transportation: Water transportation down Maurice River to Delaware Bay, thence to Philadelphia, or elsewhere. Rail transportation from Millville to Camden and Philadelphia. Large fleet of small auto trucks hauling from pits to screening plant, loading wharf, and to railroad at Millville. Steam locomotives and cars hauling from some pits to wharf. Operate own barges on the river.

Lab. No.: 504.
Location: Near Millville, Cumberland County, N. J., W. of Maurice River, from 1¼ to 1¾ miles S. of R. R. station at Millville.
Producer: G. F. Pettinos, operator.
Formation: Cohansey. Upper part may be Cape May.
Grade: Molding sand with strong bond.
Notes: Location: The northerly pit of this group. About ¾ mile due N. of office, between road and river. Superintendent called this his "molding sand pit." Transportation: Fleet of small auto trucks to wharf or to Millville as required. Dimensions: Uncertain, but apparently the remaining acreage under exactly these geologic conditions at this locality is not very large, due to the facts that the Cape May terrace is itself limited to the lower level near the river, and there has been much material taken out along here. Structure: Horizontal stratified deposit. Quite uniform for the thickness worked, so far as examined. Overburden: About 4 feet. Chiefly loose gray sand with gravel. Working Face: About 6 feet high and about 800 feet long near to and parallel with the road. Uniform yellow color. Fine grain sand with strong clay bond. Hardly any coarse material noticed. Sample taken here. Superintendent called this his "strong molding sand for steel and brass foundries." He also said that the material below this 6 foot bank, and therefore below the river level, was worked by a clam shell dredge along the river edge near by. This lower layer was said to be a slightly coarser and weaker sand, which then worked down to a depth of 12 feet below the water. This material was usually mixed with the strong material obtained from the upper bank. No sample was taken of the material dredged. Transportation: Water transportation down Maurice River to Delaware Bay, thence to Philadelphia, or elsewhere. Rail transportation from Millville to Camden and

Philadelphia. Large fleet of small auto trucks hauling from pits to screening plant, loading wharf, and to railroad at Millville. Steam locomotives and cars hauling from some pits to wharf. Operate own barges on the river.

Lab. No.: 505.
Location: Near Millville, Cumberland County, N. J., W. of Maurice River, about 2½ miles nearly due S. of R. R. station at Millville.
Producer: J. W. Paxson Co., operator.
Formation: Marine. Unconsolidated sand and gravel. Bridgeton (Pleistocene) of N. J. G. S.
Grade: Molding gravel with strong bond.
Notes: From one of stock piles near loading plant of J. W. Paxon Co. Represents mixed and screened material from two pits. Chiefly coarse material with strong bond from W. pit, plus a small amount of fine material from small pit near office. Transportation: Chiefly by water, in own barges, to Philadelphia, Pa., Works; railroad carries material from various pits to mixing and screening plant near loading wharf. Carts take it from stock piles a few hundred feet to the barges. Details regarding the west pit: Location: About ½ mile W. S. W. of office and close to road to Dividing Creek Station. Formation: Marine. Unconsolidated sand and gravel. Bridgeton (Pleistocene) of N. J. G. S. Dimensions: Large acreage. West face of large pit worked for some years. This part of pit has face about 800 feet long. Structure: Horizontal strata. Uniform for this working face. Overburden: About 3 feet. Working Face: Total height of 17 feet where steam shovel was operating. Distinct division into an upper coarse gravel bed, 5 feet thick and a lower sand bed 12 feet thick. The gravel bed is composed of coarse reddish gravel, many pebbles ½ inch in diameter, with a strong reddish bond between the grains. (All pebbles over ¼ inch are screened out before shipment.) The sand bed is more like the Bridgeton material at the Pettinos' pits a half mile north. It is composed of coarse and fine sand with strong reddish bond, chiefly iron oxide type. There is considerable crossbedding, also streaking, due to the iron oxide, also differential weathering. Method of Working: Steam shovel takes the material from bottom to top of the working face. Works railroad to screening plant near wharf, about ⅝ mile east. Method of Sampling: Sample was not taken at the pit as would have contained too much coarse gravel to have been representative. Sample was taken from the stock pile, at the screening plant, after mixing and screening. The sample was taken by filling bag direct by small portions taken from a dozen spots on the stock pile. According to the foreman, the material from this stock pile was chiefly from the full 17-foot face of the west pit just described (after screening out all pebbles over ¼ inch) mixed with a small amount of weak bonded sand from a pit near the office. Details regarding the southerly pit: Location: About ¼ mile S. E. of west pit. Visited but no sample taken. In Bridgeton formation. Lacked the distinct gravel layer of the west pit described above. Overburden: 3 feet. Working Face: 10 feet high. Chiefly fairly uniform reddish sand with little very fine material, but strong bond. Contains some clay lumps (which are mostly removed by riddling). Some streaks of fine gravel up to 6 inches in width. Below the floor level of the pit there is a sharp white or yellow silica sand, which is avoided by this operator. It is probably a coarse phase of the Cohansey formation.

Lab. No.: 506.
Location: Dorchester, Cumberland County, N. J. Pit is about ¾ mile N. E. of station. New extension of improved highway passes close to the pit.
Producer: Chas. E. Pettinos, operator. Office and loading wharf ¼ mile N. W. of station.
Formation: Cape May (marine).
Grade: Molding sand.

Notes: Transportation: Chiefly by water down Maurice River; also by rail to Camden, etc. A caterpillar tractor hauls train of small cars from pit. The tractor runs alongside the car track. The operator has been unable to get right to run his tracks across the railroad, so he carts the material from just east of railroad a few hundred feet to his loading wharf. Dimensions: Large acreage to the north. A new highway apparently will stop further operations to the east. Present working front about 300 to 400 feet long. Structure: Horizontal stratified deposit. Not very uniform along the front. Overburden: From 3 to 4 feet thick; gray sand with loose gravel. Working face from 10 to 12 feet high, chiefly yellowish sand. Strong bond chiefly due to clay. Alternate nearly horizontal bands of light yellow and dark yellow sand. Several clay streaks and a thick layer of more or less banded clay at the base. "Some of the clay goes into the mixture as shipped" (foreman). Frequent patches or areas of loose sand, free from bond. Practically no gravel seen. Method of working: As a bank, by steam shovel. Method of taking sample: Cut from a vertical strip at the working face and quartered.

Lab. No.: 507.
Location: Belle Plain, Cape May County, N. J. About ½ mile S. E. of the station.
Producer: C. E. Pettinos, operator.
Formation: Bridgeton (Pleistocene) marine.
Grade: Molding gravel.

Notes: From north bank in pit of Chas. Pettinos. Unscreened. Sample, 507 was taken on the north side of the pit. Here the materials of the working face were chiefly red, fine, strongly bonded sand, varying to very strongly bonded clay-gravel. Much of the clay and gravel is in separate thin cross bedded bands. A strip 18 inches wide was cut down the 6 foot face, piled, mixed and quartered. Dimensions: Apparently large acreage; but not all equally good material. Certain spots with weak bond or too coarse gravel are passed by in working. Working face of whole pit about 1,000 feet. Structure: Horizontal stratified deposit, with more or less cross bedding, the cross bedded structure being accentuated by the iron oxide standing out in diagonal dark colored streaks. Overburden: From 2 to 3 feet; light yellow or white unbonded sand and surface soil. Working face: About 6 feet high on an average.

Lab. No.: 508.
Location: Belle Plain, Cape May County, ½ mile S. E. of station.
Producer: C. E. Pettinos, operator.
Formation: Bridgeton (marine).
Grade: Molding gravel with strong bond. Unscreened.

Notes: Cut from northwest bank of pit. Used for heavy castings. Sample was taken about 50 feet along the working face to the west of where No. 507 was taken. Here the material has even a stronger bond than at the preceding spot, due chiefly to the very large amount of iron oxide in between the grains. There are numerous streaks of coarse sand and fine gravel, strongly cross bedded, the streaks running diagonally almost the full height of the bank. Method of taking sample, same as 508. Method of Working: By hand pick and shovel; loading onto small auto trucks. South side of pit visited but no sample taken. The material here is finer grained and with less bond than 508, and is sometimes mixed with the N. J. 8 type on request. The stratification is more nearly horizontal and the material more uniform here than at where 508 was taken. East side of pit visited but no sample taken. Here the material was rather peculiar. Grayish in tone, sticky to the touch, almost gummy, very strongly bonded, chiefly small gravel and coarse sand. The coarser streaks contain frequent small grains of decayed feldspar; "chalk pebbles" the men call them. This particular material is shipped on request to certain parties who wish a strong bonded molding gravel and do not mind the light color. Dimensions: Apparently large acreage; but not all equally good material. Certain spots with weak bond or too coarse gravel are passed by in working. Working face of whole pit about 1,000 feet. Structure: Horizontal stratified deposit, with more or less cross bedding, the cross bedded structure being accentuated by the iron oxide standing out in diagonal dark colored streaks. Overburden: From 2 to 3 feet; light yellow or white unbonded sand and surface soil. Working face: About 6 feet high on an average.

Lab. No.: 509.
Location: Clayville, Cumberland County. Several pits within radius of ¾ mile of Clayville station.
Producer: W. Golden, operator.
Grade: Molding gravel.

Notes: This sample was taken from inside of railroad car near Clayville station. Trucks were bringing loads from the pit described under No. 510 and from another about ½ mile northwest of Clayville station, formerly operated by Whitehead Bros. Co., and dumping them alternately into the car. Two men in the car were mixing the material in rather a crude and imperfect way with hand shovels. The sample is therefore presumably representative of the material from the two pits.

Lab. No.: 510.
Location: Clayville, about ¾ mile S. W. of station.
Producer: W. Golden, operator.
Formation: Bridgeton.
Grade: Molding gravel, sent to iron foundries.

Notes: Dimensions: Large acreage; but material varies in quality from spot to spot. These are relatively small pits; this one, which is the main one, having a working face about 400 feet long. Structure: Horizontal stratified deposit. Not very uniform along the working face. Overburden: Only one to two feet. Loose sandy loam. Working face: From 8 to 10 feet high; yellow to

reddish brown in color. Material rather too variable to be of high grade or to be economically worked on large scale. Largely gravel and coarse sand. Little fine grained material. Strongly bonded. Crossbedded; at times on a large scale with curving streaks, simulating folding. Wavy streaks at times have a vertical range of 6 feet. Clay streaks usually less than one inch thick; some larger ones. The clay streaks are discarded as far as possible. Streaky patches of fine grained white unbonded sand are retained. Coarse gravel is said to be screened out; but there is no screening plant here. At one place in the pit they were throwing the material by hand through an inclined screen. The fact that this is a new development may explain crude methods. Method of working: As a bank, by hand shovelling. Material carried by auto trucks to Clayville station. Method of taking sample: By shovelling small portions from face, where the men were working. Representative of material as removed, not screened.

Lab. No.: 511.
Location: Landisville, Atlantic County.
Producer: M. R. Taggert & Co., operator.
Formation: Bridgeton.
Grade: Molding gravel.

Notes: Pit and screening plant ¼ mile north of Landisville station. Dimensions: Large acreage adjacent, but not owned by this operator. Working face of pit, about 500 feet long; operations limited to about 100 feet at present. Structure: Horizontal stratified deposit. No typical gravel layer at the top, as is common in the Bridgeton. Overburden: From 3 to 5 feet; chiefly loose gray sand and gravel. Working face: About 12 feet high. Three rather distinct parts in the section. At the top a tough layer, about 4 feet thick, dark red, with scattered small gravel, some fine gravel in thin streaks, considerable coarse sand and much red clay and iron oxide bond. The next 3 or 4 feet is composed chiefly of yellowish sand, rather loose, in streaks, and with some streaks of fine yellow gravel. The lower 3 or 4 feet is chiefly reddish sand. Method of working: As a bank by steam shovel. Method of taklng sample: Cut from the top to near the bottom of the working face; mixed and quartered. Material like sample is screened (usually on ¼" screen) at the plant a few hundred feet from pit.

Lab. No.: 512.
Location: Cedar Lake, Atlantic County.
Producer: M. R. Taggert & Co.
Formation: Bridgeton.
Grade: Steel molding sand.

Notes: Dimensions: Small. About worked out. Structure: Horizontal stratified deposit. Practically no gravel in this pit. In old pit across the railroad to the east, there is a typical Bridgeton cap of reddish gravel with iron crusts which was removed with the overburden when that pit was worked. Overburden: Of from 3 to 3½ feet sand. A little gravel and some iron crusts were removed with the sand. Working face: About 6 feet high

at main front, thinning down to about 3 feet. Appears to be approaching exhaustion, so far as the good material is concerned. Working face about 100 to 150 feet long. The part mined is a dark yellowish sand, practically free from gravel. Method of taking sample: Cut from top to bottom of working face, mixed and enough taken to fill bag.

Lab. No.: 513.
Location: Folsom, Atlantic County, one mile S. of station.
Producer: C. E. Pettinos, operator.
Grade: Strong silica sand, used for steel molding.

Notes: Formation. Marine. Cohansey (Pliocene?) of N. J. G. S. Dimensions: Extensive pits. Presenting working face about 400 feet long. Structure: Horizontal stratified deposit. Well stratified; very little cross bedding. Overburden: A little over 6 feet removed. Gravelly material with reddish layer carrying iron crusts near the contact. Overburden apparently Bridgeton formation. Working face: About 22 feet in height. Yellowish, fine grained sand, with streaks of white sand. Bond is clay. There are some very thin gray clay streaks which are allowed to go along in the material as shipped. Method of working: Hand shovelling into wagons which carry material short distance, then dumped directly into flat cars. Method of taking sample: Collected from railroad cars ready to ship. (This the only fair way to obtain an average sample here.)

Lab. No.: 514.
Location: Newtonville, Atlantic County.
Producer: C. E. Pettinos, operator.
Formation: Bridgeton.
Grade: Core gravel or coarse Millville gravel, for cores.

Notes: Transportation: Rail to Camden or to Raritan Bay. Narrow gauge railroad ½ mile from pit to main railroad. Dimensions: Working face about 400 feet long. Structure: Horizontal stratified deposit. Some crossbedding, but stratification dominantly horizontal and marked by streaks of gravel up to one inch pebbles. Overburden: Of 2 feet removed by steam shovel. Working face: About 8 to 9 feet high. Rather uniformly colored dark reddish bed, numerous gravel streaks mostly horizontal. Gravel ranges up to one inch in diameter. Strongly bonded; chiefly by clay. Grains rounded, subangular, larger ones mostly quartz, some feldspar, a few hornblende; smaller grains are partly decayed feldspar. The material is screened on a ½ inch screen before shipping. Beneath the gravel as dug, there is a layer of sharp sand and gravel without bond that forms the floor of the pit. Method of working: By steam shovel cutting and direct loading into small cars. Method of taking sample: From steam-shovel-mixed material at the face. Selected to give average sample.

Lab. No.: 515.
Location: Richland, Atlantic County.
Producer: G. F. Pettinos, operator.
Grade: Richland molding gravel. For cores and heavy castings.

Notes: Transportation: By rail to Camden, etc. Two railroads intersect here. Small two-wheeled carts carry material from pit to mixer. Operator: George F. Pettinos, 1206 Locust St., Philadelphia, Pa. Dimensions: Extensive pits. Production estimated at 100 tons daily. Structure: Horizontal stratified deposit. No details in notes. Overburden: 2 feet. Working face: Is 10 feet high. Material chiefly gravel, with considerable bond; chiefly clay. Material is screened in various ways before shipping, though usually on a ¼ inch screen. No mixing here to vary the bond. Method of working: By steam shovel cutting. Method of taking sample. Taken from steam-shovel-mixed material at face, before screening.

Lab. No. 516.
Location: Downer, Gloucester County.
Producer: S. W. Downer, owner.
Formation: Cohansey.
Grade: Steel molding.
Notes: Transportation: By rail to Camden, etc. Load directly into railroad cars on a siding. Dimensions: Extensive pit and acreage. Working face about 600 feet long. Structure: Horizontal stratified deposit. Crossbedding conspicuous. Two zones, an upper dominantly yellow and a lower dominantly white. Overburden: Varies from 2 to 5 feet in thickness and consists of surface soil under which is a gravel probably belonging to the Bridgeton formation. Working face: From 20 to 22 feet high. In general it is divisible into two zones. The upper zone of yellow bonded sand, from 3 to 10 feet in thickness, constitutes the real molding sand. Sample 516 is from this zone. The lower zone is dominantly pure white unbonded quartz sand which is shipped chiefly for use for furnace linings in acid furnaces. Sample 517 is from this lower zone. The sands in both layers are crossbedded and the lower white zone contains many thin strips of yellow sand and vice versa. Method of working: Electric shovel, operated from adjoining electric transmission line by a transformer, loads the material direct into railroad cars. Method of taking sample: Sample 516 cut from face—upper zone—mixed and quartered. Sample 517, cut from face—lower zone—mixed and quartered.

Lab. No.: 517.
Location: Same as 516.
Grade: Refractory sand.

Lab. No.: 518.
Location: Blenheim, Camden County.
Producer: Cummings Bros., operator.
Formation: Kirkwood (Miocene).
Grade: Fine molding sand or molding loam. Used for brass and somewhat for aluminum.
Notes: Transportation: By rail to Camden, etc. Carted to siding near the station. Dimensions: Small pit; working face about 60 feet long. Structure: Horizontal stratified deposit; decidedly crossbedded but on small scale, the laminae being very thin. See further, below under "working face." Overburden: Thin, about one foot thick in most places. At a few places consists of 3 feet of strong gravel. Working face: About 11 feet high. All very fine, so fine that it is almost an earth, considerable of it is almost clay; no gravel at all. Laminated and violently cross-

bedded on very small scale. Contains numerous white mica flakes of small size, more abundant in upper part. Upper part light greenish brown in color, more strongly bonded than below. Lower part of alternating white clay bonded fine sand and thin light red sand bands, the latter 1/32 inch thick, colored by iron oxide. The upper stronger bonded and lower weaker bonded portions are mixed by hand shoveling to give a good mixture. Method of working: Barred down and hand shovelled, carted to siding and loaded on cars. Method of taking samples: Taken as average material from car ready to ship.

Lab. No.: 519.
Location: Lumberton, one mile N. of station.
Producer: J. W. Paxson Co., operator.
Formation: Cape May (Pleistocene).
Grade: Molding loam or Lumberton loam. Used in mixtures with gravel for iron casting and for fairly heavy pipe work.
Notes: Transportation: By rail to Camden, etc. By carts to railroad. Dimensions: About 15 to 20 acres uncut. Structure: Merely a uniform horizontal layer of very fine sand close to the surface. Overburden: From 6 in. to 20 in. of top soil only is removed. Working face: A shallow bank cutting in a level field. The molding sand in all of these pits near Lumberton and Mount Holly is the subsoil layer on the various farms. Here it varies from 1 ft. 7 in. to 2 ft. 9 in. in thickness. It is nearly structureless in appearance in the bank; is yellowish brown in color and is a very fine sand, almost a loam. Some rounded quartz grains, some white mica specks and some dark particles of glauconite can be distinguished among the grains. The bottom limit of cutting is the contact with a sharp quartz sand. Method of working: Top soil removed by hand shovelling from a long narrow strip ahead of other operations. Molding sand then cut out by hand shovels along a bank whose face is at right angles to the strip that has been cleared of overburden. Material is hand shovelled into carts, hauled to elevated loading platform and dumped into the railroad cars. (This is the general method in this Lumberton-Mt. Holly region. Method of taking samples: Vertical cuts made at several points along the working face, material mixed and sample taken. Represents average material.

Lab. No.: 520.
Location: Lumberton, one mile S. of station.
Producer: Brennan Sand Co., operator.
Formation: Cape May (Pleistocene).
Grade: Molding loam. Lumberton loam.
Notes: Transportation: By rail to Camden, etc. Possibly also by barge via Rancocas Creek to points on the Delaware and to Tullytown, Pa. Dimensions: Reported that there are 100 acres not dug off as yet. Structure: Practically as in case of Sample 519. Overburden: One to 3 feet top soil. Working face: In general, same as for Sample 519. Here it is 2 to 3 feet high. Molding sand in upper part contains some plant materials so that some otherwise good material has to be cut away with the top soil as overburden. Method of working: As in case of Sample 519. Method of taking sample: As in case of Sample 519.

Lab. No.: 521.
Location: Smithville, Burlington Co., ½ mile S. of station and 2¾ miles N. E. of Lumberton.

Producer: M. R. Taggert Co.
Formation: Cape May (Pleistocene).
Grade: Molding loam. Lumberton loam.
Notes: Transportation: By rail to Camden, etc. Hauled by carts to railroad loading platform. Operator: M. R. Taggert & Co., 854 N. 3rd St., Philadelphia, Pa. Dimensions: Forty acres uncut. Approximately 2 feet layer of molding sand along a 1200-foot front. Overburden: About 1 foot, 3 inches of top soil. Working face: About 2 feet of molding sand. Material of same general character as Sample 519 and other "Lumberton" sand. Shipped as it is dug. Method of working: Cut by hand as usual in this region, loaded on carts and hauled about ½ mile to railroad loading platform. Sometimes as many as 8 carts working. Method of taking sample: Cut in vertical strips from various parts of face, mixed and sample taken from the pile.

Lab. No.: 522.
Location: Mount Holly, Burlington County. About one mile S. E. of Mount Holly station and two miles N. E. of Lumberton, on the Carlton Jones farm.
Producer: G. F. Pettinos.
Formation: Cape May (Pleistocene).
Grade: Molding loam. Lumberton loam. Used for iron casting, pipe fittings, etc.
Notes: Transportation: By rail to Camden, etc. Fleet of light trucks haul from pit about ¼ mile to railroad. Operator: George F. Pettinos, 1206 Locust St., Philadelphia, Pa. Dimensions: Reported that this operator has bought the sand on 200 acres here. Part of this acreage is across the road from present operations. Working face about 400 feet long. Overburden: From 2 to 2½ feet of top soil removed. Working face: Two to 3 feet of molding sand. The material varies somewhat in quality, that is, in strength of bond, and is mixed in proportions desired. The character of the sand is practically the same here as in the pits nearer Lumberton. See description of Sample 519. Method of working: Loaded by hand into light trucks. Method of taking sample: Cut in vertical strips from working face and mixed. Represents average strength and grain.

Lab. No.: 523.
Location: Birmingham, Burlington County.
Producer: Norcross & Edwards, operators.
Formation: Cape May (Pleistocene).
Grade: Not used steadily. Molding sand.
Notes: Transportation: By rail to Camden, etc. By carts for short distance to railroad. Dimensions: About 30 acres are available for this operator. Structure: Simple horizontal layers of soil and sand. Overburden: Above the molding sand layer here there is a layer of 2 to 3 feet of unbonded fine yellow quartz sand as well as about 1 foot 6 inches of top soil. This is a relatively thick overburden for this region. Doubtful if the molding sand layer alone could be used profitably here, for this reason. Working face: About 2 feet of molding sand, beneath the above described overburden. Yellow brown, strongly-bonded molding sand, typical Lumberton type (see Sample 519) grading into yellow unbonded sand below as well as above. Might be utilized more successfully if mixed with a high class Lumberton loam along with some of the unbonded sand above and below the

molding sand layer. This operator is not interested in foundry or molding sands; and only supplies molding sand upon demand from his regular customers for other sands. The pit is therefore only worked at rare intervals. Method of working: Not being worked at time of visit. When worked, probably by hand cutting off of top soil and upper non-bonded sand and hand cutting of molding sand. Then loaded into carts and hauled to railroad. Method of taking sample: Vertical cuts of the 2-foot layer of molding sand only at two points, mixed and quartered.

Lab. No.: 524.
Location: Near Hainesport, Burlington County.
Producer: J. W. Paxson Co., operator.
Formation: Cape May (Pleistocene).
Grade: Lumberton fine molding sand.
Notes: Transportation: By rail to Camden, etc. Carts haul from pit about ½ mile to loading platform. Dimensions: About 50 acres said to be yet uncut. Structure: Simple horizontal layers of soil and sand; show practically no stratification lines. Overburden: From 2 to 3½ feet of pale yellowish unbonded sand carrying some glauconite grains, above which there is about 6 inches of top soil with organic material. Working face: About 2 to 3 feet of fine brownish yellow bonded sand, with numerous glauconite grains. Not notably different from other material dug in this Lumberton region. See Sample 519. Downward operations limited by a sharp unbonded sand. Method of working: By hand shovelling as described in connection with No. 519. Carts haul material about ½ mile to loading platform on siding. "Sometimes the output is from 2 to 4 railroad cars per day." Method of taking sample: Several slices down the front of the molding sand layer, mixed and sample taken from the mixture.

Lab. No.: 525.
Location: Bridgeboro, Burlington County.
Producer: Hainesport Mining & Transportation Co.
Formation: Cape May (Pleistocene).
Grade: Not used for foundries.
Notes: Transportation: By water via Rancocas Creek and Delaware River to Philadelphia, narrow gauge railroad from pit to loading platform where can be dumped into barges, as this operator's other sands are. Operator: Hainesport Mining and Transportation Co., Beach and Berk Sts., Philadelphia, Pa. Dimensions: Considerable acreage owned by the company and worked by them for other sands appears to have the layer sampled present near the surface. Structure: Horizontal stratified deposit. Overburden: Two feet of top soil. Working face: The layer sampled is about 3 feet in thickness. Light yellow fine sand with a few glauconite grains. Not very strongly bonded. Below the layer sampled there is about 15 feet of white or gray high silica sand. Method of working: The material sampled is now taken along with the 15 feet of sharp sand below it by a great steam dredge of the clam shell type that makes its cut down from the top along the edge of the bank. To get the molding sand alone the dredge would have to cut it off first and then get the rest of the material in a second cutting. Method of taking sample: A vertical cut was made across the possible molding sand layer as above described, the material mixed, quartered and sampled.

Lab. No.: 526.
Location: Near Burlington, Burlington County. Farm of C. James, about ¾ mile S. E. of the station.
Formation: Cape May (Pleistocene).
Grade: Not used.
Notes: Transportation: Is only a short distance from the railroad from Mt. Holly to Burlington, so that there would be rail transportation to Camden or Trenton and elsewhere. Operator: None at present. Farm owned by C. James, Burlington, N. J. Dimensions: Good acreage probably underlain by material similar to that sampled. Structure: Simple horizontal layers, showing very little stratification. Overburden: From one to 3 feet of top soil and unbonded sand with organic material. Probably thickens to the south. Working face: None at present. The exposure was in a temporary cut being made by a steam shovel to enable the State Highway Department to get material for a nearby fill. From 2½ to 3 feet of brown sandy loam, beneath the above described overburden. Not much bonding material. At base of exposure there is a rather coarse unbonded sand. Method of taking sample: A vertical cut was made across the sandy loam layer, the material mixed and quartered and sample taken.

Lab. No.: 527.
Location: Near Perth Amboy, Middlesex County, N. J. Florida Grove Road and New Brunswick Ave.
Producer: L. H. McHase Co.
Formation: Raritan (Upper Cretaceous).
Grade: Molding sand.
Notes: Transportation: By rail to all points; railroad adjoins the pit. Overburden: Comprises about six feet or more of sand and very coarse gravel belonging to the terminal moraine (Wisconsin). Rests upon the clays and sands of the Raritan formation. Dimensions: A very large clay pit. Working face: The Raritan beds constitute the working face; chiefly worked for clays, incidentally for sands, which are shipped for use for various purposes. These Raritan layers show very rapid variations in the character of the materials along the walls of the pit, such as from clay to coarse gravel, or to white sand, yellow sand with crusts, etc. Method of working: So far as molding sand is concerned, the method is to select from among the various sand layers in the Raritan those which are regarded as the kind desired. This sample of what they call their "molding sand" is as nearly representative as possible where the cutting is by the pick and choose method. Their "molding sand" is apparently a refractory sand. Method of taking sample: Cuts from various places, mixed and sample taken.

Lab. No.: 528.
Location: New South Amboy, Middlesex County.
Producer: Sayre & Fisher Land Co.
Formation: Raritan (Upper Cretaceous).
Grade: Molding sand.
Notes: Transportation: By rail to South Amboy, Sayreville, and other points. Also possible to ship by water, after short haul in carts to Raritan River. Operator: Sayre and Fisher Land Co., Sayreville, N. J. Overburden: The portion discarded comprises about

3 feet of top soil and fine yellow unbonded sand with numerous roots through it. Working face: The portion of the bank cut for molding sand comprises 2 feet of fine sand, light yellow brown and gray in small patchy areas slightly bonded, 3 feet of fine gray white quartz sand very slightly bonded with a few glauconite grains and a very few mica flakes and 3 feet of fine sand of same character as above, but strongly bonded with clay and with small sporadic ¼ inch pebbles. Beneath layers just enumerated, there is a layer of gravel which is not mined. Method of working: Not worked for molding sand deliberately —molding sand operations incidental to obtaining clay for brick making which occurs in other parts of the same pit. No other details in notes. Method of taking sample: Vertical cut made across the part of bank worked for molding sand (as described above under "working face"), mixed and quartered and sample taken.

Lab. No.: 529.
Location: About ½ mile S. W. of South Amboy, Middlesex County.
Producer: Such Clay Co., operator.
Formation: Raritan (Upper Cretaceous).
Grade: Steel molding sand.
Notes: Transportation: By rail to South Amboy and other points. Dimensions: A large clay pit. Overburden: About 2 feet of surface soil, then about 3 feet of gravelly yellow sand. The contact between this material and the next material below it is uneven or "pockety." Working face: Beneath the above described overburden there is about 9 feet of fine yellow and white sand, with thin clay strips which are removed in working the sand layer for molding sand. Under the layer just described there is a layer of sandy-clay and then pure white clay. The pit is primarily worked as a clay pit, the molding sand being removed to get at the clay and sold as a by-product. Method of taking sample: A vertical cut was made across the molding sand layer, mixed and quartered and sample taken.

Lab. No.: 530.
Location: One-half mile W. of South Amboy, Middlesex County.
Producer: Whitehead Bros., operators.
Formation: Pensauken (Pleistocene) and Raritan (Upper Cretaceous).
Grade: Fine molding sand, medium strong.
Notes: Transportation: By rail to South Amboy and other points. Dimensions: Operations extensive; but from place to place instead of from a single pit. Overburden: Variable. Where sample 530 was taken there was only a few inches of material removed and discarded. Working face: Variable. Where sample 530 was taken the molding sand layer was 4 feet thick and consisted of a fine medium strong yellow sand. Method of working: The company's operations are extensive but sporadic, consisting of innumerable cuttings throughout the region, where they pick and choose such material as they desire, ranging from fine strong loams to rather coarse sands and fine gravels. These they mix in such proportions as they require at their loading plant. No. 530 was from a vertical cut across the molding sand layer described under "Working face," the material being first mixed and quartered.

Lab. No.: 531.
Location: One-half mile W. of South Amboy, Middlesex County.
Formation: Same as No. 530.
Grade: Coarse sand or fine gravel with good bond.
Note: Sample taken from different stock pile than No. 530 at loading plant. Exact source of material unknown.

Lab. No.: 532.
Location: One-half mile W. of South Amboy, Middlesex County.
Formation: Same as No. 530.
Grade: Very fine molding loam used in mixtures.
Note: Sample taken from different stock pile than No. 530 at loading plant. Exact source of material unknown.

Lab. No.: 533.
Location: Same locality as 527.
Formation: Same as No. 527.
Grade: Coarse foundry sand.
Notes: Overburden: At the point in the pit where this sample was taken the overburden comprised from 6 to 12 feet of reddish boulder or gravel clay. It belongs to the terminal moraine. Working face: Between the glacial material and a thick Raritan clay there is here a layer of sand varying from 0 to 15 feet in thickness, also belonging to the Raritan formation, which is the material sampled. This varies from white silica sand to fine gravel with much clay intermixed, brown strongly bonded coarse sands, wavy clay streaks and clay lumps. The output is varied to suit demand. Method of taking sample: Mixed from various places in bank to provide a sample of somewhere near the average product.

Lab. No.: 534.
Location: About ¾ mile E. of Flanders, Morris County.
Producer: Acme Silica Co., operator.
Formation: Sandstone of Silurian.
Grade: Steel molding sand.
Notes: Transportation: By rail to Dover, N. J. and Phillipsburg, N. J., and other points. By trucks from pit and plant to Flanders station. Dimensions: The pit is 60 to 70 feet deep, 200 feet wide and over 400 feet long. No other data in notes. Structure: The beds of sandstone dip about 70 degrees to the Southeast. Some of the beds carry lines of pebbles, ranging up to 2" in diameter. Overburden: From 6" to 8" of old glacial drift (supposedly Kansan), stripped off. Working face: About 60 feet high, inclined beds of white sandstone that is rather friable and easily crushed. Method of working: The sandstone is drilled, blasted, carried to crushing plant, goes through jaw crusher, then elevated and put through rolls again elevated to sieves. Tailings are re-rolled. Most of material is screened through ⅛ inch screen; sometimes through 1/16 inch screen. As shipped the material is a white, nearly pure quartz grit. Method of taking sample: Taken from leading chute.

Lab. No.: 535.
Location: About two miles N. E. of Hackettstown, Warren County, and ½ mile S. W. of Saxton Falls.
Formation: Glacial deposit.
Grade: Not used.
Notes: Transportation: By rail to points east and west of Hackettstown. Operator: Eastern States Sand & Gravel Corp., 26 Cortland St., New York City. Dimensions: No data in notes. For-

mation: Glacial. Terminal Moraine, Wisconsin of N. J. G. S. Overburden: None removed. All material taken at present. Working face: The cut shows 6 inches of top soil, 2 feet of yellow very gravelly fairly strong bonded subsoil, and a foot or two of drift, composed of quartz, with some grains of feldspar and some ferromagnesian minerals, unbonded. Method of working: The pit is now worked for paving and building sand and gravel. A portable bucket excavator and drag line remove the sand which is then washed. The washings are in proportion to 1 to 10; that is they get 1 part of washings to every 8 ot 10 parts of sand and gravel. Of the washings they could produce about one or two railroad cars a day. It is a fine grained sand with small bond.

Lab. No.: 536.
Location: Phillipsburg, Warren County.
Producer: Steckel Sand Co., operator.
Formation: Stratified glacial deposit.
Grade: Fine molding loam.
Notes: Transportation: By rail to Phillipsburg and other points. By carts a few hundred feet to the railroad cars. Dimensions: Probably not very extensive at a workable thickness; less than 10 acres at the most. Overburden: Where the molding sand layers occurs it is covered by from 12" to 18" of top soil. Working face: The molding sand layer is from 2½ to 3½ feet high. The material is a light yellowish brown, very fine even grained, strongly clay bonded loam or sand. As indicating the strength of the material, it could be clamped around a lead pencil, and when the pencil was withdrawn, a perfectly smooth, hexagonal bore would be left. Impressed the collector as probably equal to the best material around Lumberton and Mt. Holly. Method of working: Loaded into carts and hauled 300 feet to railroad cars. Method of taking sample: Vertical cuts from the molding sand layer, mixing and quartering.

Pennsylvania

Lab. No.: 601.
Location: Burnham, Mifflin County.
Producer: L. H. Miller.
Formation: Probably Oriskany sandstone (crushed).
Grade: Steel sand.

Lab. No.: 602.
Location: Montoursville, Lycoming County.
Producer: Lycoming Silica Sand Co.
Formation: Disintegrated Portage standstone.
Grade: Cores and plaster.

Lab. No.: 603.
Location: Hamburg, Burks Co.
Formation: Recent alluvium.
Grade: Heavy iron castings.

Lab. No.: 604.
Location: Hamburg, Burks Co.
Formation: Recent alluvium. Contains a few pebbles, mainly decomposed schist and quartzite, about ⅓" diameter.
Grade: Heavy iron castings.

Lab. No.: 605.
Location: Berne, Burks Co.
Producer: Schuylkill Valley Sand Co.
Formation: Recent alluvium. Contains a few quartzite pebbles, about ¼" diameter. Some limonite grains on 40 and 70.

Lab. No.: 606.
Location: Slatedale, Lehigh Co.
Producer: L. P. Rex.
Formation: Glacial lake deposit. A few soft pebbles consisting of sand cemented by limonite.

Lab. No.: 607.
Location: Allentown, S. E.
Producer: F. A. J. Miller.
Formation: Disintegrated gneiss. A few angular pebbles of decomposed quartzite, about ¼" diameter.
Grade: Cores.

Lab. No.: 608.
Location: Pit west of Emans.
Producer: C. O. Hunsiker, Allentown.
Formation: Recent.
Grade: For castings under 100 lbs., and brass castings. Claimed to be good for aluminum.

Lab. No.: 609.
Producer: Northern Refractories Co., Ridgway.
Formation: Sand contains a few pebbles of sandstone about ¼" diameter. A few mica flakes on 40—270 mesh screens.

Lab. No.: 610.
Producer: Northern Refractories Co., Ridgeway.
Formation: Contains a few pebbles mainly of decomposed sandstone about ¼" diameter.

Lab. No.: 611.
Location: Catawissa.
Producer: G. F. Pettinos.
Grade: Medium.

Lab. No.: 612.
Location: Catawissa.
Producer: G. F. Pettinos.
Grade: Fine.

Lab. No.: 613.
Location: Tullytown.
Producer: G. F. Pettinos.
Formation: Contains a few quartzite pebbles about ⅓" diameter.
Grade: No. 0.

Lab. No.: 614.
Location: Tullytown.
Producer: G. F. Pettinos.
Grade: No. 4.

Lab. No.: 615.
Location: Winfield, Pa.
Producer: Winfield Sand Co.
Grade: No. 1.

Lab. No. 616.
Location: Winfield, Pa.
Producer: Winfield Sand Co.
Grade: No. 2.

Lab. No.: 617.
Location: Winfield, Pa.
Producer: Winfield Sand Co.
Grade: No. 3.

Lab. No.: 618.
Location: Emlenton.

Lab. No.: 619.
Location: Emlenton.

Lab. No.: 343.
Location: Danville.
Producer: Gulick Sand Co.
Grade: No. 6.

Tennessee

Lab. No.: C-1.
Location: Fish Springs, Carter Co., Tenn., Southern Ry., Mt. City Division, 15 miles N. E. Elizabethton and 38 miles S. E. Bristol. Sand deposit borders railroad. Fish Springs Sand Co.
Producers: J. E. Cable and W. E. Grindstaff, Fish Springs, Tenn.
Formation: Recent river deposit. Dimension, 500 ft. long, 50 ft. wide. Depth not fully known. Structure, flat river deposit. Overburden, sand and a few inches of soil and vegetation. Texture: (a) Uniform approximately. (b) Sharp and angular to subrounded. Bonding material: Clay and some iron oxide. Comp. minerals: Chiefly sand. Lime: Little or none. Consolidation: Loose. Impurities: No lumps. Method of working: Bank and pit.
Grade: Molding sand.

Lab. No.: C-2.
Location: Braemar, Tenn., Carter Co. Six miles S. E. of Elizabethton on E. Tenn. and N. C. & St. L. Rys. (narrow gauge) and Laurel Fork Ry. (standard gauge).
Producer: Owner: Pittsburgh Lumber Co., Braemar.
Formation: Residual sand on Laurel Fork Creek. Dimensions: Very long, 30′ x 2,000′ wide, and few feet to 25′ deep. Length

extends up and down the Laurel Fork six miles. Structure: Flat beds and very uniform, but some pebbles. Overburden: Thin soil up to 12 in. Distribution of grains: Rather uniform size. No cross bedding; grains subrounded—rounded. Bonding: Bonding material silica and clay and some iron. Composition: Silica and little else; no mica. Calcareous: Little or none. Consolidation: Not consolidated. Impurities: No lump, few gravel, no mica. Method of working: Pit. Sample method: Face of bank 4 ft.

Grade: Molding sand.

Lab. No: 243 (C-3).

Location: Wautauga Station. Wautauga River, property of J. H. Smalling, Johnson City, Route No. 5. End of spur of 2 miles of E. Tenn. & Western N. C. Ry., from Wautauga Point. Two miles E. Southern Ry. Wautaga Station, 5 miles E. of Johnson City.

Producer: Was known as Watauga Sand Co., now as J. H. Smalling Sand Co.

Formation: Bedded river sand, very compact, residual. Dimensions: Underlies 12 acres; thickness not known. Structure: Bedded and quite uniform. Overburden: 8' building sand and 10 plus in. soil. Distribution of grains: Rather uniform in size of grain. Rounded to subrounded grains. Bonding material: Fairly high; mostly clay and some iron oxide. Mineral composition: Mostly silica, some feldspar, little or no mica. Lime: Little or none. Consolidation: Very compact—dynamite used to loosen it. Impurities: No lumpy impurities outside of a few gravels and sometimes a little limonite. Method of working: Pit.

Grade: Molding sand.

Lab. No.: 242 (C-4).

Location: One-eighth mile east of Mt. Olivet Station on the L. & N. Ry. and four miles south of Knoxville.

Producer: Owner: W. L. Berry & Sons, Route No. 3, Knoxville, Tenn.

Formation: Residual sand from some nearby sand formation. Dimensions: Mined to a depth of 20'. length 220' and width 60'. Probably molding sand over an area of 1,500' x 1,200' and depth undetermined. Uniformity: Very uniform. Overburden: Little to 8 in. Distribution of grain in texture: (a) Uniformly mixed. (b) No irregular beds. (c) Grains subrounded to angular, very fine. Bonding material: Clay and water high. Mineral composition: Chiefly silica. Calcareous matter: Little or none. Consolidation: Fairly consolidated, plough used in shipping it. Impurities: Few gravels but no lumps. Method of working: Bank.

Grade: Molding sand.

Lab. No.: C-5.

Location: One-fourth mile S. E. of terminus of street car line at St. Elmo, and at base of Lookout Mt. on the Tennessee-Georgia state line.

Producer: Owner: W. J. Bradford, St. Elmo, Tenn.

Formation: Residual sand and clay from the shale and sandstone formations higher up on Lookout Mt. Dimensions: Occurs in some quantity, but it is impossible to make any estimate. The sand is weathered talus sandstone and shale material. Uniformity:

Not uniform, but has small white streaks of disintegrated sandstone and shale. Overburden: Very thin loam and soil averaging 12 in. thick. Grain texture: Not uniformly mixed. Subrounded to angular. Sand uniform in size. Bonding material: Clay and ferric iron. Suited for rather heavy work. Used by many of the 28 foundries in Chattanooga. Mineral Composition: Chiefly silica grains. Calcareous matter: Very small in calcareous matter and some portions show none. Consolidation: Very compact but handled with pick. Impurities: Small sand rock and quartzite concretions. Considerable rotten wood. The size of concretions runs up to 2 in. in length. Method of working: Bank method.

Grade: Building and molding sand.

Lab. No.: 1.
Location: One mile west of Roger's Springs, lower sand layer below line of pebbles.
Formation: Lagrange. Light gray to yellow sand, 1½ to 10 ft. thick. Underlies No. 2.

Lab. No.: 2.
Location: On Southern R. R. one mile west of Rogers Springs. Upper sand layer.
Formation: Lagrange. Coarse red sand, 2 to 5 ft. thick. Overburden 1 to 2 ft.
Grade: Not used.

Lab. No.: 3.
Location: Durden's Sand Bank, Saulsbury.
Formation: Lagrange. Deposit 25 ft. thick with 8 ft overburden.
Grade: Cores.

Lab. No.: 4.
Location: Durden's Sand Bank, Saulsbury, Hardeman Co.
Formation: Lagrange. Reddish brown sand 7 ft. thick with 1 ft. overburden.
Grade: Some sold as molding sand. Most of it discarded.

Lab. No.: 5.
Location: One mile S. of Grand Junction, Hardeman Co. Highest sand layer in bank.
Formation: Lagrange. Reddish brown clayey molding sand 3 ft. thick. Overburden, 4 to 5 ft.

Lab. No.: 6.
Location: One mile S. Grand Junction.
Formation: Lagrange. Brown sand, 6 ft. thick, under No. 5.

Lab. No.: 7.
Location: La Grange, Tenn. One-fourth mile E. of E. A. Stafford's house, on his land.
Formation: Lagrange. Deposit 3 to 5 ft. thick.
Grade: Molding sand.

Lab. No.: 8.
Location: One-eighth mile E. of Mr. E. A. Stafford's house, on his land, La Grange.
Formation: Lagrange. Deposit 6 ft. thick.
Grade: Molding.

Lab. No.: 9.
Location: Where road running S. crosses branch railroad ¾ mile E. of La Grange.
Producer: Dale Sand Co., owner.
Formation: Lagrange. From bank 15 ft. thick.
Grade: Core.

Lab. No.: 10.
Location: Two and one-half miles S. W. of Bolivar, 500 to 800 ft. N. of railroad crossing.
Formation: Lagrange sand. Coarse red clayey sand, 5 ft. thick. Underlies No. 11.

Lab. No.: 11.
Location: Two and one-half miles S. E. of Bolivar; bank on roadside 500 to 800 ft. N. of railroad crossing.
Formation: Columbia loam. Deposit represents upper 4 ft. of section.

Lab. No.: 12.
Location: One and one-fourth miles S. E. Saulsbury on S. A. Daniel's land, bank; sample from gully on N. side of road.
Formation: Lagrange. Dark red clay sand, 5 ft. thick, with overburden of 3 ft. quartz sand and 5 ft. loam.

Lab. No.: 13.
Location: One and one-half miles S. E. Saulsbury, Hardman Co., on S. A. Daniel's land, bank; sample from gully on N. side of road.
Formation: Lagrange. Sample of upper 15 ft. of a 30 ft. bed of sand underlying No. 12.

Lab. No.: 14.
Location: Rossville, Tenn., on Dr. West's land, ¼ mile E. of junction of M-s road through Rossville, on old State Line road.
Formation: Lagrange. Brownish red sand, 4 to 5 ft thick. This is overlain by 6 ft. red sandy clay and 4 ft. loam.

Lab. No.: 15.
Location: One and one-half miles E. of Rossville, on land of Mrs. Smith along old State Line road.
Formation: Lagrange. Red sand 5 ft. thick, overlain by 2 ft. clay, and 4 ft. loam.

Lab. No.: 16.
Location: On Mrs. R. R. Wheeler's estate, Moscow, Tenn., at site of yellow fever grave yard, ¼ mile E. of No. 17.
Formation: Lagrange. Sample from deposit 7 ft. thick; overburden 3 ft.

Lab. No.: 17.
Location: Estate Mrs. R. R. Wheeler, Moscow, Tenn.
Formation: Lagrange. Light yellow sand, 7 ft. thick, with 6 ft. overburden.
Grade: Molding sand—not used at present.

Lab. No.: 18.
Location: R. Galloway's land, Saulsbury, Tenn. First 3 to 5 ft. below surface, clay.
Formation: Lagrange. Brown sand 3 to 5 ft. thick, with 1 to 3 ft. overburden.

Lab. No.: 19.
Location: Small gully on N. side of road, ½ mile S. of Selmar on land of Wm. McKellar.
Formation: Ripley. Deposit not less than 9 ft. thick. A red sand.

Lab. No.: 20.
Location: One and one-half miles S. of Henderson, Chester Co., on W. O. Mitchell's land, 200 feet E. of Henderson and Finger road.
Formation: Quaternary terrace. A brown, loamy sand, 1 ft. 3 in. thick. Overburden 8 in.

Lab. No.: 21.
Location: One and one-half mile S. of Henderson, Chester Co., on land of W. O. Mitchell, 200 ft. E. of Henderson and Finger road.
Formation: Quaternary terrace. Light yellow sand, 6 ft. thick, underlying No. 20.

Lab. No.: 22.
Location: Four miles E. of Jackson on land of R. A. Hurt; gully on S. side of N. C. & St. L. Ry.
Formation: Lagrange. Brown sand, 5 ft. thick; overburden, 6 ft. clay.

Lab. No.: 23.
Location: Four miles E. of Jackson on land of R. A. Hurt; gully on S. side of N. C. & St. L. Ry.
Formation: Lagrange. Deposit brown and yellow sand 8 ft. thick and underlying No. 22.

Lab. No.: 24.
Location: One mile N. of Jackson, W. side of road on land of Al Muse.
Formation: Columbian loam. A surface loam 2 ft. thick. Probably includes some fine sand below the loess.

Lab. No.: 25.
Location: Four miles N. of Jackson on land of W. B. Hopper; gullies on E. side of road, upper 2 ft. of sand—overburden 6 ft. (loess and red clay).
Formation: Lagrange. Red sand, 2 ft. thick. Has 4 ft. loam overburden and overlies No. 26, with which it could be mixed.

Lab. No.: 26.
Location: Four miles N. of Jackson on land of W. B. Hopper; gullies on E. side of road, sample from 3 to 6 ft. of sand below that included in No. 25. There is no distinct boundary between the two.
Formation: Lagrange. Coarse red sand, 3 to 6 ft. thick, underlying No. 25.

Lab. No.: 27.
Location: Four and one-half miles N. of Jackson, bank on roadside about one mile E. of Illinois Central R. R.
Producers: Bedford White and W. B. Hopper, owners.
Formation: Lagrange. Deposit of red sand 8 ft. thick, with 5 to 8 ft. overburden of loam and red clay.

Lab. No.: 28.
Location: Three miles N. of Jackson, about 1½ miles W. of M. & O. R. R., from Mrs. Gilman's land.
Formation: Lagrange. Red and brown sand 6 to 7 ft. thick, with overburden of 3 to 8 ft. of clay.

Lab. No.: 29.
Location: One-half mile N. of Medon; bank on E. side of road. Four feet of sand below loess.
Producer: Owner: Peoples Savings Bank, Jackson, Tenn. Manager, R. B. Swink, Medon, Tenn.
Formation: Brown sand 4 ft. thick, with 3 ft. of loam overburden. Beneath it is 7 ft. brown and white sand.

Lab. No.: 30.
Location: One-fourth mile N. E. of Jackson corporation limits.
Producers: Owners: Curtis Hurt, J. R. Dent, D. Weiss.
Formation: Red sand 3 ft. thick. Overburden 3 ft. loam.
Grade: Molding large and medium iron castings.

Lab. No.: 31.
Location: Two miles N. E. of Lexington Court House. Roadside cut. Land of R. W. Howard, Lexington.
Formation: Ripley. Reddish brown sand 2-3 ft. thick. Loam overburden 2-6 ft.

Lab. No.: 32.
Location: Upper 4 to 6 ft. of bank on S. side of N. C. & St. L. R. R. at Hollow Rock Junction.
Producer: Owner: N. C. & St. L. Ry.
Formation: Quaternary terrace deposit. Red loamy sand 4 to 6 ft. thick and of considerable extent. Little overburden.

Lab. No.: 33.
Location: One-half mile S. S. W. of Sawyers Mills.
Producer: J. J. Cole, owner.
Formation: Ripley. Deposit 9 ft. thick and tests made on average Sample.
Grade: Molding sand.

Lab. No.: 34.
Location: One-half mile S. Sawyers Mills.
Producer: W. R. Cole, owner.
Formation: Ripley. Tests represent average of 6½ ft. bed.
Grade: Molding sand.

Lab. No.: 35.
Location: One and one-fourth miles W. N. W. of Huntingdon Court House.
Producer: S. G. Aden, Huntingdon, owner.
Formation: Alluvial. Deposit 6 ft. thick.

Lab. No.: 36.
Location: Two and one-half miles N. 10-15°, W. of Huntingdon Court House. About 50 ft. above base of La Grange.
Producer: W. W. Bute, Huntingdon, owner.
Formation: Lagrange. Deposit consists of 4 ft. silt loam overlying 8 ft. of the sand represented by above tests.

Lab. No.: 37.
Location: Three hundred ft. W. of Sawyers Mill Station on N. side of N. C. & St. L. tracks.
Producer: J. J. Cole, owner.
Formation: Ripley. Sample represents lower 7 ft. of deposit.
Grade: Molding sand.

Lab. No.: 38.
Location: Three hundred ft. W. of Sawyers Mill Station.
Producer: J. J. Cole, owner.
Formation: Ripley. Sample represents upper 4 ft. of the deposit.
Grade: Molding sand.

Lab. No.: 39.
Location: Eight hundred ft. N. of Sawyers Mill Station (back Zack Postoffice).
Producer: J. J. Cole, owner.
Formation: Ripley. Deposit 12 ft. thick. Consists of alternating layers of white and brown sand, each about 3 in. thick.
Grade: Not used.

Lab. No.: 40.
Location: Lipe, one mile E. of Sawyers Mill.
Producer: C. F. Nionelly's main pit.
Formation: Ripley. Tests were made on average sample of the bank, exclusive of 2.5 ft at top.
Grade: Molding.

Lab. No.: 41.
Location: Lipe, one mile E. of Sawyers Mill. Lower part of sand.
Producer: J. W. Jordan pit.
Formation: Ripley. From 5 ft. bed of fine, light gray sand.
Grade: Molding sand.

Lab. No.: 42.
Location: Lipe, one mile E. of Sawyers Mill. Upper part of sand.
Producer: J. W. Jordan pit.
Formation: Ripley. Fine yellow sand, from 4-ft. bed in same bank as No. 41. Mixed with 41 for shipment.
Grade: Molding sand.

Lab. No.: 43.
Location: Springville, Benton Co., Tenn., ¼ mile S. W. of station.
Producers: H. H. Fitch, John Clymer, owners.
Formation: Ripley. A 7-ft. bed of yellow sand overlain by 2 ft. of sandy loam.

Lab. No.: 44.
Location: One mile N. of Whitlock. R. R. cut.

Producers: Mrs. C. H. Jackson, Route 4, Puryear, Tenn., J. W. Works & Co., Whitlock, Tenn., owners.
Formation: Ripley. Light brown to yellow sand, 7 ft. thick.

Lab. No.: 45.
Location: Two miles N. of McKenzie, Tenn., ¼ to ⅓ mile N. of Henry County line.
Producer: J. O. Manly, owner.
Formation: Lagrange.

Lab. No.: 46.
Location: Obion County, Tenn., 6 miles E. of Tiptonville near foot of bluff where road to Tiptonville intersects road along foot of bluff on S. side of Gladys Hollow.
Producer: Albert M. Rains, owner.
Formation: Loess.

Lab. No.: 47.
Location: Dyersburg, Tenn. Cut on Illinois Central Railroad, 500 ft. N. of station. Lower 7 or 8 ft. of bank (less weathered portion).
Producer: Wiz. Butterworth, owner.
Formation: Loess. Deposit 8 ft. thick.

Lab. No.: 48.
Location: Dyersburg, Tenn. Cut on Illinois Central R. R. 500 ft. N. of the station; upper 7 ft. of bank (more weathered portion).
Formation: Loess. Has a sandy feel, but more properly to be classed as a fine silt or clay. Deposit 7 ft. thick.

Lab. No.: 50.
Location: One and two-tenth miles S. W. of Whiteville, Tenn.
Formation: Lagrange. A 5-ft. bed of sand overlain by 4 to 7 ft. loam and underlain by coarse loose sand.

Lab. No.: 51.
Location: Three miles W. of Somerville, Tenn.
Formation: Lagrange. Sand 7 ft. thick, overlain by 5 to 7 ft. loam.

Lab. No.: 52.
Location: One-quarter mile S. of Cox Bridge; W. bank of Hatshie River, S. E., part Hardeman Co., Tenn.
Producer: Jim Boatman, Hornsby, owner.
Formation: Alluvial. Upper 5 ft. of bank. Brownish yellow, fine loamy sand, 5 ft. thick. Overburden 6 in.

Lab. No.: 53.
Location: One-quarter mile S. of Cox Bridge; W. bank of Hatshie River, S. E. part Hardeman Co., Tenn.
Producer: Jim Boatman, owner.
Formation: Alluvial. Silty sand, 3 ft. thick, underlying No. 52.

Lab. No.: 54.
Location: Ripley, Tenn. Cut on Illinois Central R. R. ⅓ mile S. of station; 300 ft. N. of highway bridge, E. bank.
Producer: Illinois Central R. R., owner.
Formation: Loess.

Lab. No.: 55.
Location: Cut on Yazoo & Mississippi R. R. at S. city limit of Memphis.
Formation: Loess. Upper more weathered portions.

Lab. No.: 56.
Location: Cut on Yazoo & Mississippi R. R. at S. city limit of Memphis, not including 4 ft. at top of bank.
Formation: Loess. Fourteen-ft. section below No. 55.

Lab. No.: 57.
Location: Hollywood N. E. suburb of Memphis. Missouri Portland Cement Co. Washed, dredged river sand.
Formation: Lagrange and river sand mixed.
Grade: Core.

Lab. No.: 58.
Location: Memphis, Tenn.
Producer: Wolf River Sand Co., owner.
Formation: Loess.

Lab. No.: 59.
Location: Memphis, Tenn.
Producer: Wolf River Sand Co., owner.
Formation: Loess. Underlies No. 58.

Lab. No.: 60.
Location: Bank of Tenn. River, directly opposite Shiloh National Cemetery (Pittsburg Landing).
Producer: Dr. F. C. William, Corinth, Miss., owner.
Formation: Quaternary terrace. Upper 11 ft. of bank.

Lab. No.: 61.
Location: Three-quarter mile N. of Swallow Bluff Landing. Deposit 2-4 ft. thick. Overburden 8 in.
Producer: Mrs. Elizabeth Bogin, Decaturville, Tenn.

Lab. No.: 62.
Location: Three miles N. of Savannah, Tenn.
Producer: Sam Williams, Savannah, owner.
Formation: Quaternary terrace. Deposit 3 to 5 ft. thick.

Lab. No.: 63.
Location: Parsons, Tenn., R. R. cut E. of town.
Formation: Eutaw. Sand averages 5 ft. in thickness. Exposed for about ¼ mile. One foot loam overburden.

Lab. No.: 64.
Location: One-half mile S. of Perryville. Alluvial river bottom sand.
Formation: River sand.

Lab. No.: 65.
Location: One and one-half miles E. of Darden, Henderson Co., Tenn. Beach on river bottom.
Formation: Alluvium. Deposit 3 ft. thick. Overburden 6 in.

Lab. No.: 66.
Location: Three miles S. E. of Lexington, Henderson Co., Tenn., one-half mile N. of R. R. roadside bank.
Producer: George Azbill, owner.
Formation: Ripley. Red brown sand 3 ft. thick, with 8 in. overburden.

Lab. No.: 68.
Location: Three miles S. E. of Lexington on road to Parsons, ½ mile N. of R. R.
Producer: George Azbill, owner.
Formation: Ripley. Light gray and yellow sand, 8 ft. thick, overlain by 3 ft. of No. 66.

Lab. No.: 69.
Location: Two miles S. E. of Lexington, Henderson Co., Tenn., going up hill on E. side of second branch crossed on road from Lexington to Parsons, about 0.6 mile N. of R. R.
Formation: Ripley. Deposit of whitish sand 30 ft. thick.

Virginia

Lab. No.: 1.
Location: Armstrong property, Petersburg.
Formation: Aquia formation. Limonite stained sand, 6-8 ft. thick, which grades into white sand below and with which it is mixed for brass work.
Grade: Brass.

Lab. No.: 2.
Location: Armstrong property, Petersburg.
Formation: Aquia formation. A nearly white sand, 2-3 ft. thick, which is mixed with No. 1, and used at Appomattox Iron Works.
Grade: Brass castings and also small iron castings.

Lab. No.: 3.
Location: From pit between old and new channels of Appomattox River at Petersburg.
Formation: Patuxent. The deposit varies from 8 to 12 feet; material whitish when fresh; consists largely of quartz pebbles with a white clay bond.
Grade: Known as Dixie core sand. Used for cores and heavy green sand molds for large castings. See also No. 99.

Lab. No.: 4.
Location: One mile E. of Petersburg, on Hopewell Concrete road, on property of Encampment Realty Company.
Formation: Patuxent. Deposit shows 2 feet overburden and 25-30 feet gravel. Could be screened to separate the pebbles. Deposit fairly uniform. Sand and pebble grains coated with iron stain.

Lab. No.: 5.
Location: Petersburg Sand & Gravel Corporation, Roslyn plant.
Formation: Patuxent. The deposit consists of gravel and sand, which is put through a washing and screening process. The sand could probably be used in core work.

Lab. No.: 7.
Location: Puddledock Plant, Dixie Sand & Gravel Co.
Formation: Patuxent. Sample represents the washed sand.

Lab. No.: 8.
Location: Hopewell.
Formation: Calvert. Deposit 5 feet thick. Quite extensive and lies immediately under surface loam.

Lab. No.: 11.
Location: Petersburg-Lakemont.
Formation: Patuxent. Run of pit.

Lab. No.: 12.
Location: One mile W. of Petersburg.
Producer: Perkinson & Finn.
Formation: Aquia. Material similar to samples 1 and 2. Has been worked for 15 years. Deposit sometimes too clayey.
Grade: Molding sand.

Lab. No.: 13.
Location: Petersburg.
Formation: River sand. Material dredged from sand bar in Appomattox River. Should be screened to remove coarse pebbles.

Lab. No.: 15.
Location: Hampton Roads Sand & Gravel Co. Plant one mile S. E. of Port Walthall station, on R. F. & P. R. R.
Formation: Patuxent. The sample represents washed fine sand.

Lab. No.: 16.
Location: Perkinson property, one mile N. of Carson, on Atlantic Coast Line.
Formation: Calvert. Section shows 4 to 5 feet molding sand. Top 2 ft. is reddish and lower 2-3 ft. white. The sample tested is a mixture of the two.

Lab. No.: 18.
Location: On Holliday place, one-fourth mile N. of Huska station.
Formation: Patuxent. Deposit of sand and gravel about 12 ft. thick. Covers probably 40 or 50 acres. Material has no bond.

Lab. No.: 19.
Location: Arundel Sand & Gravel Company, on flats of Swift Creek and James River, seven miles N. E. of Petersburg.
Formation: Patuxent. The sample represents sand from washer.

Lab. No.: 22.
Location: Old Dominion Sand & Gravel Co., on Swift Creek, four miles N. of Petersburg.
Formation: Patuxent. The sample represents fine sand from washer.

Lab. No.: 24.
Location: Snead Place, Chester, Chesterfield County.
Formation: Aquia. A bed of molding sand 7 to 8 ft. thick, with 4-5 ft. overburden.
Grade: Molding sand.

Lab. No.: 25.
Location: N. G. Stiegelder pit, on Crillis Creek, near Richmond.
Formation: Aquia. The molding sand, which is about 10 ft. thick, is overlain by 2-3 ft. overburden, and underlain by greensand, which is not used.
Grade: Heavy and light iron castings.

Lab. No.: 26.
Location: Stiegelder pit, on Crillis Creek, near Richmond.
Formation: Aquia. This represents the greensand referred to under No. 25.

Lab. No.: 27.
Location: Highland Park, near Richmond.
Formation: Aquia. On C. & O. R. R. near Laundry Crossing, at Highland Park, Richmond. This sample and 28 were taken from different parts of the same face. Six ft. stripped off above the sand.
Grade: Molding sand.

Lab. No.: 28.
Location: Highland Park, near Richmond.
Formation: Aquia. See No. 27.
Grade: Molding sand.

Lab. No.: 29.
Location: Pit. N. side of Almond Creek, one-half mile west of James River.
Producer: A. Caredo.
Formation: Aquia sand 4 to 6 ft. thick, with 7 to 9 ft. gravel overburden.
Grade: Molding sand.

Lab. No.: 30.
Location: Just S. of Wilton Creek on road from Richmond to Varina Grove.
Formation. Calvert. A ferruginous loamy sand, fully 7 ft. thick. Is quite typical of the formation in this region, although this particular deposit is not in a good location for working.

Lab. No.: 31.
Location: Harvey's pit on old Cox farm, one mile S. W. of Dutch Gap on James River.
Formation: Patuxent. Section exposed about 40 ft. thick. A mixture of stones, gravel, sand and clay. The finer portions when screened out make a core sand with appreciable bond. Below this is a sand deposit which could probably be used in steel casting.
Grade: Core sand.

Lab. No: 32.
Location: River sand from James River at Richmond.
Formation: Alluvium.

Lab. No.: 34.

Lab. No.: 35.
Location: Pit on Almond Creek, near Richmond.
Producer: W. L. Caredo.
Formation: Aquia. Deposit of sand 6 ft. thick, with 12 to 15 ft. overburden, which is stripped off.
Grade: Iron molding.

Lab. No.: 36.
Location: On road from Chester to Centralia, where it crosses R. F. & P. R. R.
Formation: Aquia. A 4 ft. bed of sand, with 2 ft. overburden.

Lab. No.: 37.
Location: On road from Chester to Centralia, where it crosses R. F. & P. R. R.
Formation: Aquia. This sample represents a more clayey phase of No. 36.

Lab. No.: 38.
Location: On road from Chester to Centralia, where it crosses R. F. & P. R. R.
Formation: Aquia. This sample represents the sandy overburden.

Lab. No.: 39.
Location: Along the road from Falmouth, Stafford County, to Washington, and just E. of Falmouth.
Formation: Deposit about 15 ft. thick as exposed. Has a few pebbly streaks. Underlain by a white clay bonded sand similar to that from Dutch Gap, but not as coherent.

Lab. No.: 40.
Location: On main Washington pike along Accokeek Creek, and one mile N. of W. from Brooks.
Formation: Patuxent. Deposit about 20 ft. thick. Lower half, which this sample represents, is a whitish sand with clay bond.

Lab. No.: 41.
Location: On main Washington pike, along Accokeek Creek, and one mile N. of W. from Brooks.
Formation: Patuxent. Sample represents upper half of bank mentioned under No. 40. Material and iron stained sand with clay bond, and some clay pellets.

Lab. No.: 42.
Location: On main road just S. of Stafford Court House.
Formation: Aquia. Deposit of fine grained, iron stained molding sand with maximum exposed thickness of 12 ft. Overburden not over 3 ft.

Lab. No.: 43.
Location: W. of Quantico, near main road.
Formation: Patuxent. Deposit of whitish and iron stained sand about 6 ft. thick.

Lab. No.: 44.
Location: W. F. McColl property, near S. of Aquia Creek, Stafford County.
Formation: Aquia. A fine grained molding sand. Exposure about 12 ft. thick, but very abundant.

Lab. No.: 45.
Location: One-eight mile S. E. of Stafford Court House.
Formation: Aquia. Deposit as exposed fully 10 ft. thick. A fine grained molding sand.

Lab. No.: 46.
Location: Two miles E. of Fredericksburg.
Formation: Aquia. Molding sand from 9 to 11 ft. thick, with 6 ft. overburden, which consists of gravelly loam.

Lab. No.: 47.
Location: One-half mile N. W. of King George, King George County.
Formation: Calvert. Deposit about 12 ft. thick.

Lab. No.: 48.
Location: R. F. & P. Ry. Washer.
Formation: Patuxent. Sample represents washed sand.

Lab. No.: 49.
Location: Massaponyx Sand & Gravel Co.
Formation: Patuxent. Sample represents coarse washed sand. Could be used in cores.

Lab. No.: 50.
Location: Fredericksburg.
Formation: River sand. Dredged from Rappahannock River. Might do for cores.

Lab. No.: 51.
Location: Massaponyx Sand & Gravel Co., five miles S. E. of Fredericksburg.
Formation: Patuxent. Sample is fine sand from washer.

Lab. No.: 52.
Location: N. of Milford.
Formation: Aquia. The deposit shows about 6 ft. of light iron stained sand overlain by gravel and sand. It is located along the R. F. & P. R. R.
Grade: Iron and brass molding.

Lab. No.: 53.
Location: Back River, near Norfolk.
Formation: Beach sand.

Lab. No.: 54.
Location: Cape Henry.
Producer: Jones Sand & Gravel Co.
Formation: Dune sand.
Grade: Cores.

Lab. No.: 55.
Location: Cape Henry.
Producer: Atlantic Sand Company.
Formation: Dune sand.
Grade: Cores.

Lab. No.: 56.
Location: Willoughby Spit, near Norfolk.
Formation: Beach sand.

Lab. No.: 57.
Location: Dismal Swamp.
Formation: Swamp sand.

Lab. No.: 59.
Location: Near Franklin.

Lab. No.: 60.
Location: Mount Airy, Curlis property.
Formation: St. Mary. A 15 ft. deposit, of which lower 4 ft. is more iron stained. Shipped by boat on Chickahominy River. Extensive sand deposit.
Grade: Molding.

Lab. No.: 61.
Location: Almond Creek, near Richmond.
Formation: Aquia. Sample taken from lower 8 ft. of deposit. About 15 per cent quartz pebbles greater than ¼ inch.
Grade: Molding and cores.

Lab. No.: 62.
Location: S. E. of Disputanta.
Formation: Calvert. Represents a lens in the Calvert formation and resembles Millville gravel.

Lab. No.: 63.
Location: Monroe Bridge, S. of Franklin.
Formation: A very few pebbles—consist mostly of quartz about ¼ inch in diameter—are present. Flakes of white mica on sizes 70 to 270 inclusive.

Lab. No.: 64.
Location: Swamp sand along Nottoway River.

Lab. No.: 65.
Location: Scotland Yard.
Formation: St. Mary's.
Grade: Molding sand.

Lab. No.: 66.
Location: Coggins Point.
Formation: Nanjemay.

Lab. No.: 67.
Location: Providence Forge, Parker Place.
Grade: Fine oil core work.

Lab. No.: 68.
Location: Providence Forge.
Producer: American Sand & Gravel Co.

Lab. No.: 69.
Location: Providence Forge.
Producer: American Sand & Gravel Co.
Grade: Filler sand.

Lab. No.: 70.
Location: On Chickahominy River, near Boulevard P. O.
Producer: C. Weber.
Grade: Core.

Lab. No.: 71.
Location: Just E. of Boulevard P. O.
Formation: Calvert or St. Mary's, section of face.
Grade: Molding sand.

Lab. No.: 72.
Location: Just E. of Boulevard P. O.
Formation: St. Mary's. Represents 2 ft. of oxidized glauconite sand.

Lab. No.: 73.
Location: One-half mile S. E. of Diascund Bridge, James City Co.
Formation: White sand slightly iron stained, 8 ft. thick. Overburden clay 3 ft. thick.

Lab. No.: 74.
Location: Yorktown, on College Creek, just S. of Williamsburg.
Formation: Yorktown.

Lab. No.: 75.
Location: Bank of Scrimmin's Creek.
Formation: Yellow white sand.

Lab. No.: 76.
Location: Scrimmin's Creek.
Formation: Same as 75. Brown mottled part of No. 75 and could be worked separately in places.

Lab. No.: 77.
Location: One and one-half miles N. W. of Peeke's Turnout, and ¼ mile W. of R. R.
Formation: Aquia.

Lab. No.: 78.
Location: Eight miles N. W. of West Point.
Formation: Six ft. bed coarse sand.

Lab. No.: 79.
Location: Near Urbana, Gloucester Co.
Formation: Four ft. bed. Resembles coarse Lumberton somewhat.

Lab. No.: 80.
Location: Near Center Point.
Formation: Calvert.

Lab. No.: 81.
Location: Three-fourths mile W. of Milford.
Formation: Aquia.

Lab. No.: 82.
Location: Four miles from Milford and 1½ miles from South River.
Formation: Pleistocene.

Lab. No.: 83.
Location: Cash Corners, King George Co.
Formation: Brown sand, 10-12 ft. thick.

Lab. No.: 84.
Location: Cash Corners, King George Co.
Formation: White sand, 4-6 ft. thick under 83.

Lab. No.: 85.
Location: One-half mile S. E. of mouth of Potomac Creek, King George Co.
Formation: Nanjemay. Sand averages 5 ft. thick and overlain by 0-5 ft. overburden.

Lab. No.: 86.
Location: Two and one-half miles from Montross.
Formation: Calvert. Sandy diatomaceous earth.

Lab. No.: 87.
Location: Just beyond National Cemetery on Richmond Pike, Fredericksburg.

Lab. No.: 88.
Location: Near Lathrop & Ruffins workings, 5 miles S. E. of Fredericksburg.
Formation: Aquia.

Lab. No.: 89.
Location: Alexandria.
Formation: Four ft. sand overlain by 4 ft. clay.
Grade: Iron molding.

Lab. No.: 90.
Location: Hunting Creek along River Road near Alexandria.
Formation: Pleistocene.
Grade: Coarse work and cores.

Lab. No.: 99.
Location: Petersburg.
Formation: Patuxent.
Grade: Dixie core sand from works of Newport News Shipbuilding Company.

Lab. No.: 100.
Location: Highland Park near Richmond.
Formation: Aquia.
Grade: Steel sand.

Lab. No.: 307.
Location: Scottsville.
Formation: Floodplain. A few pebbles of quartzite about ¼" diam. On 70-270 inches a few flakes of mica and magnetite sand.

Lab. No.: 308.
Location: Stapleton, Lee property.
Formation: Residual. A few small angular pieces of decomposed quartzite, which could be crushed between the fingers.

Lab. No.: 309.
Location: Hollins Mill near Lynchburg.
Formation: Creek deposit.

Lab. No.: 310.
Location: Madison Heights, near Lynchburg.
Formation: Residual. Has been used for small castings, but burns out quickly. 70-270 inclusive show a few mica flakes. 6-40 inclusive contain some plant rootlets.

Lab. No.: 312
Location: Chatham.
Formation: River sand. A few pebbles of quartzite and mica gneiss about ¼" diam. 40-270 inclusive contain a few mica flakes.

Lab. No.: 313.
Location: Danville.
Formation: River sand. The sample collected had been washed and screened. A few chert pebbles about ¼ inch diameter, 70-200, inclusive, contain a few mica flakes.

Lab. No.: 314.
Location: Schoolfield, near Danville.
Formation: River sand. Represents washed sand. A few pebbles of gneiss and chert, mostly about ¼ inch diameter. 12-270, inclusive, show a few mica flakes.

Lab. No.: 315.
Location: Danville.
Formation: River sand. A few angular pebbles, chiefly gneiss, about ¼ inch diameter. Mica flakes fairly abundant.
Grade: Used now only in asphalt, but similar to some core sands.

Lab. No.: 318.
Location: Salem. Pit lies in flood plain of Roanoke River, 2½ miles N. E. of Salem. Contains pebbles and stones, and has to be screened.
Formation: Floodplain deposit. A few pebbles, mainly flat pieces of shale, about ⅓ inch diameter. 20 and 40 mesh contains a few shell fragments.
Grade: A little in cores.

Lab. No.: 323.
Location: Delton.
Formation: Floodplain along New River. Deposit forms lenses in other kinds of river sand. Sold occasionally for local use.
Grade: Molding sand.

Lab. No.: 324.
Location: Delton.
Formation: Floodplain deposits; added to annually.
Grade: A coarse sand thus far used only for plaster. Could be used for cores.

Lab. No.: 326.
Location: Petersburg.
Formation: Patuxent.
Grade: No. 3 of Perkinson & Finn. Collected at General Chemical Works, Pulaski.

Lab. No.: 329.
Location: Kermit.
Formation: Oriskany sandstone. A round grained sandstone which is crushed, screened, washed and sold for glass. Could be used for steel sand.

Lab. No.: 330.
Location: Kermit.
Formation: Oriskany sandstone. Same material as 329, but not as white. Resembles it closely in texture.
Grade: No. 3 sand from glass pits.

Lab. No.: 331.
Location: Kermit.
Formation: Oriskany sandstone. This is refuse material from the preparation for market of 329 and 330. It is coarser, and could be used for cores.
Grade: Tailings from glass washer.

Lab. No.: 332.
Location: Silica.
Formation: Oriskany sandstone.

Lab. No.: 333.
Location: Silica.
Formation: Oriskany sandstone.
Grade: No. 2 grade.

Lab. No.: 334.
Location: N. Holston.
Formation: Mississippi sandy shale. Outcrops along railroad. Represents more sandy phase of shale formation in that vicinity. Would have to opened up if used.

Lab. No.: 336.
Location: Wytheville N. slope of Lick Mountain.
Formation: Cambrian. This material represents disintegrated sandstone. Could be used in cores, and is not unlike some steel sands. A considerable quantity on the lower slopes of Lick Mountain. Two mile haul to railway.

Lab. No.: 337.
Location: Pearisburg.
Producer: New River Sand & Gravel Co.
Formation: River deposit. Similar to sand used at small foundries for cores. This material gave 49.13 per cent on ¼ inch sieve. The pebbles are quartzite and chert, averaging ¾ inch diam., 70-270, inclusive, contained a few mica flakes.

Lab. No.: 338.
Location: Pearisburg.
Formation: Floodplain. Car sample from Buchanan pit. Sand similar to that used at some foundries for cores. A few quartzite pebbles about ¼ inch diameter, 70-270, inclusive, with some mica.

Lab. No.: 339.
Location: Pearisburg, Dillard pit.
Formation: Floodplain. Sample taken from car. Sand similar to that used at some foundries for small cores. Very similar to 338. The two pits are in the same deposit, about 500 ft. apart. A few quartz pebbles about ¼ inch diameter, 40-270, inclusive, a few mica flakes.
Grade: At present only in construction work.

Lab. No.: 340.
Location: Eggleston, Tom Cuddy pit.
Formation: Floodplain. Not unlike floodplain material used by foundries at other points in Virginia.

Lab. No.: 342.
Location: Buena Vista.
Formation: Floodplain. Deposit lies along river. Is 4 ft. thick and underlain by coarse sand. Has been used about 20 years. Contains some clay streaks. Sand said to show a tendency to cause scabs.
Grade: Iron casting. Some brass.

Lab. No.: 344.
Location: Basic.
Formation: Floodplain.
Grade: Iron molding.

Lab. No.: 346.
Location: Goshen.
Formation: Oriskany sandstone.

Lab. No.: 348.
Location: Winchester.
Formation: Floodplain.

Lab. No.: 349.
Locateion: Lipscomb.
Formation: Disintegrated sandstone.

Lab. No.: 351.
Location: Clifton Forge.
Formation: Residual sand from a sandy limestone. A local deposit, as is often the case with this type. The sandy parts of the deposit are dug for local use. About 3 parts of used sand are mixed with 1 part green sand.
Grade: Iron molding.

Lab. No.: 352.
Location: Port Republic.
Formation: Floodplain. Deposit shallow and of limited extent.
Grade: Plowshares.

Lab. No.: 353.
Location: Elkton.
Formation: Floodplain deposit along South River. Said to be inferior to No. 352.
Grade: Iron molding at Harrisonburg.

ALABAMA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	* Bond Strength	* Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
1	Gadsden				.14	.30	7.80	12.44	6.00	19.86	2.32	.72	50.24	99.82	1304	4.2 6.6 8.8 11.0 12.7	...... 204.4 237.3 **250.3** 210.0	12.12 **28.97** 18.44 ....
2	Gadsden					.76	6.50	26.20	13.06	24.82	2.74	.12	25.78	99.98	344	4.2 6.0 8.2 10.0	96.0 **138.6** 107.2	...... 39.34 **41.76** 38.92
3	Gadsden				.06	.28	9.28	12.04	7.42	17.68	.08	.34	52.62	99.80	1704	6.7 9.2 11.1 11.9 13.4	194.8 **266.9** 257.1	...... 21.48 27.39 27.58 **34.58** Wet
4	Gadsden					.06	3.52	11.84	7.90	17.06	.76	.28	58.96	100.38	904	6.3 8.9 10.8 12.2	191.6 **210.4** 201.4	...... 12.10 **13.12** 9.05
5	Gadsden					.10	5.12	13.74	7.80	25.20	1.10	.36	46.56	99.98	1040	6.4 8.4 9.9 12.6	206.6 **209.5** 190.5	15.57 17.21 **17.96** 13.56
6	4 Miles S. Attalla				.90	1.24	1.20	.80	1.04	11.80	1.24	.44	81.34	100.00	872	6.5 8.2 10.1 12.3 13.5	148.7 **164.3** 155.1	...... 4.19 4.67 **5.20** 4.56
7	Attalla					.64	31.72	22.74	5.20	5.26	.48	.08	33.56	99.68	1272	4.8 6.5 8.5	137.9 **304.5** 234.6	66.40 **73.85** 60.19
8	Reads Mill				.48	1.10	7.68	6.38	4.92	14.22	1.34	.10	63.78	100.00	936	8.5 10.3 11.9	189.2 **195.8** 189.7	12.98 **15.03** 10.02
9	Wellington Station				.08	.74	26.78	22.34	9.02	17.56	1.92	1.42	20.08	99.94	144	3.3 5.0 6.3 8.7	72.1 **82.7** 81.1	72.01 88.8 **98.3** 92.8
10	Wellington Station				.04	1.64	31.26	27.34	6.40	13.48	2.20	5.16	12.46	99.98	144	3.9 6.0 8.3 9.2	98.7 106.6 **117.1** 102.8	29.43 41.46 **50.36** 49.01
11	Wellington Station					.74	17.94	14.04	5.20	4.80	.04	.....	57.24	100.00	744	6.2 8.4 10.0 12.3 14.0	180.7 206.7 **224.8** 208.8	3.11 4.85 6.72 **8.27** 6.82
12	Benjamin Station				.38	4.54	41.40	21.40	6.76	9.02	.56	.38	15.14	99.58	344	2.3 4.0 6.1 10.4	117.2 **123.3** 101.5	...... **92.30** **96.57** 81.71
13	Benjamin Station				.04	.20	8.48	13.00	6.80	13.36	1.34	.50	56.28	100.00	904	6.9 8.8 11.0 11.2	245.5 **247.2** 219.2	...... 15.59 **22.30** 16.40
14	Benjamin #1 Station			1.06	.28	3.12	26.48	14.22	3.88	5.06	.22	.02	45.66	100.00	1336	4.4 7.4 9.2 9.5	...... 263.9 **276.5** 264.7	28.00 **29.49** 25.97 ......
15	Benjamin Station						.70	26.12	26.30	6.84	.06	.10	39.84	99.96	536	6.5 8.3 10.3	199.8 **205.2** 166.5	32.95 **33.62** 17.96
16	Riverside					.26	11.66	20.02	7.72	16.42	.70	.30	42.92	100.00	1304	6.8 8.7 10.2	202.6 **205.6** 198.9	17.83 **24.77** 19.90

* The heavy face type numbers in the right hand columns represent maximum bond and permeability figures.

ALABAMA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
17	Riverside.....	....	.....	.....	.....	.24	11.14	11.66	14.92	19.80	1.56	1.08	39.56	99.96	936	4.3 6.6 8.5 8.9	139.5 **209.9** 206.5	...... 16.27 **19.47** 18.93
18	Riverside.....	....	.....	.....	.....	.18	6.70	15.26	6.88	12.62	1.18	.82	56.36	100.00	1304	8.7 10.7 12.5 13.5	223.4 **243.9** 223.2	13.42 14.90 **16.68** 11.27
19	Riverside.....	....	.....	.....	....	.08	12.88	23.60	10.94	19.16	1.34	.44	31.56	100.00	840	4.1 6.3 8.4 9.7	175.8 **188.8** 167.5	...... 29.31 **30.26** 28.50
20	Cook Springs..	....	.....	.....	.30	1.64	21.24	19.90	5.76	13.40	.84	.32	36.60	100.00	936	4.8 6.6 8.2 10.5	212.6 **253.7** 251.9 231.7	43.47 **63.99** 44.03 26.46
21	Cook Springs..	....	.....	.....	.20	.72	16.70	15.00	7.06	14.66	1.18	.24	44.24	100.00	1336	5.5 8.6 10.5 12.0	206.8 **276.8** 249.9	...... 35.62 **36.69** 22.09
22	Cook Springs..	....	.....	.....	.....	.16	18.28	25.86	10.46	18.84	1.96	1.24	23.00	99.80	344	6.1 8.0 9.7	121.2 **127.3** 118.8	35.22 **37.29** 32.89
23	Cook Springs..	....	.....	.....	.....	.22	5.82	10.88	7.22	19.60	2.32	1.92	52.02	100.00	736	8.2 9.8 12.3 Mud	203.0 205.3 **238.3**	12.6 13.65 **16.23** 1.40
24	Cook Springs..	....	.....	.....	.....	.26	8.72	15.58	7.94	18.94	.80	.10	47.66	100.00	808	4.1 6.1 8.1 9.8	161.2 **206.4** 185.6 173.3	...... 9.56 **18.82** 14.89
25	Cook Springs..	....	.....	.....	.62	.12	7.36	20.60	9.00	16.24	1.86	2.88	41.20	99.88	1304	6.9 8.8 10.7 12.5	...... 236.2 **237.5** 233.8	21.15 **24.99** 23.16 12.44
26	Cook Springs..	....	.....	.....	.....	.34	9.48	10.06	5.22	20.50	1.90	.58	51.88	99.96	808	7.8 8.4 10.1 11.5	...... 203.2 **215.3** 204.1	10.82 11.53 **11.65** 10.59
27	West Anniston.	....	.....	.54	1.56	8.62	15.36	8.08	3.34	10.12	1.32	2.04	48.98	99.96	1104	6.2 8.9 10.8	191.9 **287.7** 265.0	52.79 **61.63** 42.40
28	Ragland.......	....	.....	.....	.....	.10	5.82	13.82	8.68	27.76	3.28	2.44	38.06	99.96	472	5.8 8.0 9.8	149.4 **174.0** 151.6	9.68 **15.69** 13.46
29	Ragland.......	....	.....	.....	.08	.06	6.76	15.02	8.18	23.04	2.88	1.78	42.20	100.00	744	4.9 6.1 7.8 9.6	192.9 **198.9** 193.4 184.5	...... 10.38 **13.50** 12.64
30	Ragland.......	....	.....	.....	.....	.16	25.72	32.04	10.34	16.10	1.90	1.78	11.76	99.80	176	3.4 5.6 7.0	92.3 **95.1** 94.6	68.5 **74.4** 71.8
31	½ Mile N. E. Irondale.....	....	.....	.70	.16	1.92	39.50	16.80	4.50	4.42	.56	.04	30.80	99.40	1104	2.5 4.9 6.0 8.6	...... 239.1 **242.8** 199.0	57.22 **71.52** 57.93 33.36
32	½ Mile N. E. Irondale.....	....	.....	.....	.....	1.84	33.42	12.44	3.08	3.14	.24	.04	45.80	100.00	1704	4.4 6.2 8.0	172.3 **284.4** 258.1	38.48 **46.46** 34.25
33	½ Mile N. E. Irondale.....	....	.....	1.12	.16	1.74	38.42	25.14	6.66	8.12	.02	.04	18.56	99.98	608	Dry 2.4 4.4 6.0	...... **113.5** 111.8 100.3	56.13 87.79 **94.12** 90.09

ALABAMA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Wate Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
34	Chelsea.......	....	....	.....	.....	.14	2.56	4.56	3.06	13.24	3.70	1.44	71.00	99.71	1336	7.1 9.1 10.3 13.5	218.8 228.1 239.2 237.6	7.60 12.98 9.06 7.99
35	Chelsea........	Medium Molding Sand...	....	.....	.....	.24	11.52	13.28	6.10	13.74	.96	.02	53.74	99.60	776	4.5 6.0 8.5 10.2	183.8 195.97 210.8 192.2	3.78 8.72 11.65 11.17
36	Chelsea........	Light Molding Sand...	....	...	.....	.18	12.48	18.94	8.44	19.24	.82	.04	39.86	100.00	744	4.0 6.1 7.7 9.7	169.13 180.7 165.8	9.90 19.10 23.12 20.80
37	Chelsea........	Core Sand	....	.....	.....	1.78	37.30	28.44	7.26	7.20	.18	.02	17.68	99.86	144	1.7 3.6 5.9 7.9	60.60 95.90 86.30	62.02 93.35 109.22 83.28
38	Irondale.......	....	....	.....	.....	1.26	43.28	34.02	7.02	7.38	.28	.04	6.58	99.86	72	1.3 3.4 5.2 7.6 10.3 12.8	...... 71.8 72.9 78.7 87.5 84.5	104.4 159.6 153.7 149.2 125.9 103.1
39	Chelsea........	Core Sand	....	.....	.04	.84	25.32	30.08	9.48	15.76	2.12	1.30	14.88	99.82	344	3.8 5.7 7.7	95.40 99.40 95.75	36.63 59.37 55.26
40	Chelsea........	Light Molding Sand....	....	.....	.....	.66	14.88	19.36	9.12	15.86	2.58	.02	37.52	100.00	....	1.6 3.8 6.0 8.1 9.9	96.4 175.7 174.7 157.5	5.16 10.40 20.84 25.24 25.08
41	Chelsea........	Medium Molding Sand....	....	.....	.12	.14	7.68	14.80	7.06	20.56	.90	.20	48.52	99.98	936	6.6 7.9 9.7 11.9	235.1 246.3 224.2	10.39 11.88 15.92 10.26
42	Chelsea........	Heavy Molding Sand....	....	.30	.12	1.48	15.52	10.82	4.92	14.88	3.36	2.14	46.18	99.72	872	5.9 8.2 9.5 11.9	208.6 229.6 192.8	12.67 18.27 21.13 10.12
43	Washington Ferry........	Fine Molding Sand...	....	.....	.....	.70	15.54	20.86	9.30	21.90	2.38	1.02	27.58	99.28	1272	5.2 6.1 7.5	165.52 181.90 172.54	13.76 24.78 20.17
44	Prattville......	Medium Molding Sand....	....	.....	.....	.84	20.78	26.64	10.80	19.30	1.50	.24	19.54	99.64	872	3.6 6.3 7.8 9.3 12.3	121.8 131.0 112.0	31.06 38.36 43.72 46.64 36.02
45	Jacksons Lake Sta..........	....	....	13.04	19.92	42.62	22.34	.76	.04	.06	.04	.02	.84	99.68	104	Dry	......	670.95
46	Jacksons Lake Sta..........	....	....	6.22	9.00	40.44	41.50	2.18	.10	.08	.02	.....	.42	99.96	40	Dry	......	467.54
47	Jackson Lake Station......	....	....	.40	.58	6.34	22.82	8.64	4.04	8.02	.16	.04	48.96	100.00	8	6.3 7.8 9.8 11.9	228.37 312.30 269.43	35.43 38.43 42.07 22.31
48	Coosada Station......	....	....	1.86	10.90	54.42	31.10	2.46	.60	.40	.06	.06	.....	99.86	1272	Dry	......	468.85
49	Coosada Station......	Open Molding Sand...	....	.....	.30	3.76	15.54	8.90	3.92	12.44	.58	.22	54.16	99.82	1536	8.5 10.5 12.7	278.2 307.7 270.5	24.89 34.32 27.41
50	Prattville Junction.....	....	....	35.04	22.24	27.32	14.00	.58	.26	.14	.08	.10	.....	99.76	40	Dry	......	859.69
51		....	....	3.04	7.90	41.04	43.60	3.16	.62	.48	.06	.04	.....	99.94	8	Dry	......	432.44
52		....	....	12.82	15.26	40.24	29.56	1.42	.24	.30	.02	.02	.....	99.88	40	Dry	......	470.17
53	Coosada Station......	....	....	1.72	2.88	23.58	53.60	7.50	1.44	1.86	.10	.02	7.00	99.70	336	Dry 2.1 3.6 6.1	..... 104.26 73.71 73.40	207.02 297.62 340.95 339.57

ALABAMA

Lab. No.	Locality	Grade if Used	Fineness Test On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
54	5 Miles W. Montgomery.	....	.....	2.36	6.20	45.84	30.90	2.74	.46	.62	.98	.46	.....	99.56	40	Dry	......	465.80
55	5 Miles W. Montgomery	....	.....	12.40	23.54	62.64	.02	.98	.16	.16	.02	.02	.....	99.94	8	Dry	......	676.38
56	N.Montgomery	....	.....	22.24	15.92	58.58	2.04	.90	.04	.12	.02	.06	.....	99.92	8	Dry	......	871.65
57	N.Montgomery	....	.. ..	7.44	8.86	49.10	31.22	2.54	.26	.32	.06	.02	.....	99.82	8	Dry	......	438.11
58	Toulminville...	....	.....	.....	.18	.28	7.24	16.16	7.62	17.46	2.02	.30	48.54	99.80	1936	6.6 7.4 10.6	271.77 271.86 237.2	14.39 20.85 15.56
59	Toulminville...	....	.....	.20	1.70	18.54	61.06	11.66	2.70	2.60	.62	.40	.....	99.48	104	Dry	......	125.46
60	Toulminville..	....	......	...	.16	.54	32.42	37.02	9.40	7.82	.88	.92	10.42	99.58	240	3.8 5.4 7.5	82.5 85.6 82.9	83.31 87.82 80.27
61	14 Mile Island	....	.....	.64	5.92	54.92	38.04	.32	.04	.04	.06	.02	.....	100.00	72	Dry	......	498.70
62	above Mobile	....	.....	.....	.94	6.54	70.36	15.22	4.08	1.36	.34	.42	.....	99.26	344	Dry	......	141.10
63	Mobile Bay....	....	.....	.....	.38	20.18	66.42	9.08	1.50	1.70	.18	.02	.....	99.46	104	Dry	......	163.20
64	Springhill near Mobile..	....	.....	.56	1.14	7.86	31.86	20.26	7.64	7.96	.82	.02	21.40	99.52	544	3.9 5.9 8.5	135.5 279.8 210.3	63.64 99.13 79.82
65	Springhill near Mobile..	Core Sand	.....	.....	.....	1.18	72.36	21.62	.60	2.92	.40	.40	.....	99.48	40	Dry	......	111.67
66	Flomaton.....	....	.....	14.70	9.96	25.76	38.82	7.38	1.48	1.34	.26	.02	.....	99.72	40	Dry	......	163.20
67	1 Mile E. Chehaw.....	Pipe Sand	.....	12.02	13.58	47.66	23.72	1.78	.40	.56	.06	.02	.....	99.80	40	Dry	......	498.70
68	Chehaw Spur..	....	.....	6.40	11.06	46.20	32.60	2.72	.36	.52	.04	.02	.....	99.92	40	Dry	......	460.24

ALABAMA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
469	1¼ Miles E. of Red Bay....	....	.....	.18	.06	.24	3.36	14.18	21.52	18.70	15.18	6.70	19.98	100.10	1704	4.2 6.1 7.8 9.9 11.3	159 233 226	17.8 22.7 23.4 24.2 16.7
470	1¼ Miles E. of Red Bay....	Molding..	.....	.04	.02	.12	.80	5.30	30.92	31.24	15.90	5.58	10.04	99.96	576	3.7 5.8 7.3 9.7	70 123 128 112	17.8 24.2 29.0 25.8
471	1 Mile E. of Red Bay....	Molding Sand....	.....	.....	.08	.02	1.80	4.12	6.14	4.44	7.18	39.72	36.00	99.50	2536	4.4 6.3 7.9 10.2 12.2 14.9	170 209 227 239 285 265	4.0 4.9 5.8 5.8 5.6 ......
472	1 Mile E. of Red Bay....	Molding..	.....	.....	.08	.10	7.70	17.28	28.82	18.62	10.42	6.86	9.36	99.24	1040	6.0 8.0 10.0 10.0 12.0	91 105 104	28 30 30 24.2
473	W. of Red Bay	....	12.90	19.66	6.22	.80	52.04	3.38	.82	.30	.34	.74	2.96	100.16	172	3.7 6.0 8.0	56 67 58	287 313 205
474	W. of Red Bay	....	.....	.08	.28	14.60	75.82	5.30	.92	.36	.22	.44	2.14	100.16	176	4.0 5.4 7.8 9.7 11.1	60 65 70 70.6 76	358 550 274 253 198
475	Spruce Pine....	....	6.88	20.36	7.96	9.92	45.50	5.12	1.52	.40	.30	.28	.84	99.08	8	0	......	158
476	Spruce Pine....	....	.....	.30	.78	.28	86.80	8.74	1.46	.34	.20	.30	1.06	100.26	72	0	......	159
477	Spruce Pine....	....	.....	.02	.04	.20	29.12	36.72	17.94	6.30	4.26	3.08	2.00	99.68	88	0	......	37.5
478	Spruce Pine....	Stove Sand....	.....	.....	.02	.14	25.50	29.74	18.04	9.64	6.28	5.92	4.32	99.60	176	3.0 5.6 8.1 9.5	64 83 68	62 67 62 55
479	Spruce Pine....	Molding..	1.76	.94	.42	1.82	15.30	36.98	12.10	3.14	2.24	5.04	19.50	99.24	376	3.7 6.0 7.1 8.4 9.8	147 184 171	7.2 28.0 36.0 33.0 29.0
480	Berrylum......	....	.44	2.50	7.78	27.80	51.52	6.14	1.76	.58	.48	.50	.42	99.92	40	0	......	220
481	Florence......	....	4.22	11.89	7.99	5.78	67.52	1.93	.35	.07	.03	.09	.....	99.97	72	0	......	315
482	Hobbs Island..	....	.....	.95	1.54	16.82	67.76	9.61	1.85	.55	.34	.42	.....	99.64	40	0	......	202
483	Hobbs Island..	....	2.40	16.20	7.48	9.96	57.66	4.64	.98	.26	.14	.22	.62	100.56	72	0	......	228
484	4 Miles W. of Adger........	Pipe Sand	.....	.....	.02	.02	15.48	18.80	10.66	5.94	7.54	11.30	30.20	99.96	872	6.0 8.4 10.0 12.3 12.4	230(1) 247 244	9.4 19.0 28.0 17.8 13.8
485	Tuscaloosa....	....	4.30	9.88	5.13	1.33	72.63	4.85	.96	.21	.21	.20	.....	99.79	72	0	......	197
486	Tuscaloosa....	....	.06	.20	.56	2.38	84.30	9.48	2.06	.35	.14	.12	.....	99.65	72	0	......	165
487	GraceStation..	Radiator Sand...	.14	1.22	.54	.32	8.74	12.06	9.90	5.68	5.96	11.98	43.66	100.20	....	6.5 8.9 12.5 15.6	274 308 328 236	13.4 25.8 10.3 2.2
488	Woodstock....	....	.....	.16	.26	.16	40.70	16.06	5.32	2.20	2.10	5.04	28.16	100.16	....	3.8 6.2 7.6	...(1) 354 305	49.0 105.0 93.0
489	Woodstock....	Steel Sand	.....	.16	.50	1.54	54.10	22.22	5.72	2.36	1.72	3.94	8.02	100.28		3.7 5.6 7.1 8.4 8.5	103 106 99	80 105 105 80 93
490	3 Miles N. W. Bessemer...	....	.....	.06	.12	.04	25.66	13.12	6.30	3.12	3.78	7.32	40.50	100.02	....	6.3 7.7 9.3 11.4 16.5	203 256 290 310 313(2)	7.7 12.2 23.4 45.0 1.9

(1) Too Dry. (2) Too Wet.

CALIFORNIA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
1	Pacific Grove.. Monterey Co.	Core.....	0.00	0.00	0.00	11.11	87.07	1.74	0.03	0.04	0.00	0.00	.....	99.99	72	0	......	242.83
2	Pacific Grove.. Monterey Co.	Core.....	0.00	0.00	1.56	58.09	40.26	0.02	0.00	0.00	0.00	0.00	.....	99.93	72	0	......	460.07
3	Ventura....... Ventura Co.	"Velvet" Molding Sand...	0.00	0.00	0.26	0.31	0.54	0.39	0.44	9.26	0.11	0.59	88.17	100.08	1672	4.7 6.9 8.5 10.6	...... 149.95 **152.53** 149.74	7.49 **8.81** 8.71 ......
4	Riverside..... Riverside Co.	Molding..	0.00	0.65	1.75	1.72	2.11	1.42	0.44	15.98	1.15	1.36	73.35	99.93	1440	4.4 5.7 7.6 9.8	...... 180.44 **187.90** 184.20	5.25 **6.14** 5.63 ......
5	San Diego..... San Diego Co..	Molding..	0.00	0.25	1.03	2.38	6.27	2.67	0.20	19.44	0.27	5.86	61.63	100.00	2736	3.3 4.0 6.0 8.2 9.7 11.7	199.48 **210.59** 179.73 174.60	.... 11.14 11.77 **13.28** 10.86
6	San Diego..... San Diego Co.	Molding..	0.00	0.00	0.20	0.82	3.28	2.05	1.28	2.76	0.12	0.98	88.60	100.09	5136	6.4 8.6 9.9 11.7 12.1	169.38 187.76 **193.55** 186.75	2.66 3.16 3.32 **4.00** 3.98
7	San Diego..... San Diego Co.	Molding..	0.00	0.00	0.10	0.25	0.61	0.49	0.13	11.96	0.39	5.62	80.41	99.96	4104	5.7 7.8 10.0 11.7 12.3	174.58 176.81 **177.14** 158.20	5.00 5.61 7.06 **7.86** 7.29
8	San Diego..... San Diego Co.	Molding..	0.00	0.00	0.07	0.05	0.14	0.23	0.23	21.93	0.05	5.23	72.02	99.95	2840	3.1 4.1 5.8 8.	128.88 **130.96** 128.84 124.15	9.72 10.43 **11.83** 10.06
9	4 Miles W. of Corona...... Riverside Co.	Molding..	0.00	0.00	1.43	5.78	19.84	11.23	2.11	21.49	0.68	1.79	35.54	99.89	1008	6.0 7.9 9.9	122.61 **146.10** 141.40	14.00 **15.30** 15.26
10	4 Miles S. W. Corona...... Riverside Co.	Molding..	0.00	1.46	3.58	11.84	23.27	9.75	1.85	18.11	0.12	2.97	27.05	100.00	1672	5.7 7.8 9.9 11.6 11.8	140.65 141.40 149.87 **151.59** 136.40	11.94 16.25 **16.54** 14.15 ......
11	Ben Ali Siding. SacramentoCo.	Molding..	0.00	0.00	2.71	13.11	16.45	4.33	0.21	6.04	0.00	0.00	56.05	98.90	1040	..... 2.00 3.9 5.6 7.9 10.5	.... 208.40 **215.43** 161.96	64.75 56.13 44.53 19.16 15.24 0.44
12	Decoto........ Alameda Co.	Molding..	0.00	0.00	0.00	0.49	6.38	5.71	8.38	18.46	0.01	1.00	59.55	99.98	1440	6.1 7.8 10.5 13.0	206.30 **215.49** 190.80	3.68 4.46 **5.85** 4.30

MARYLAND

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
1	Wade Pit ¼ mile N. W. of Halethorpe	Molding..	.....	.....	.....	1.70	26.66	22.70	7.46	12.40	.52	.18	28.12	99.74	336	3.5 5.4 7.3	133.3 156.0 124.8	30.34 43.60 43.23
2	Beal Cook Pit, Mt. Winans, ¼ mile E. of B. & O. R.R.	Molding..	.....	.....	.....	3.88	40.90	19.38	0.30	13.74	.80	.04	19.62	98.66	336	3.4 5.4 7.6 9.5	139.5 183.3 142.1	46.46 57.95 67.80 61.88
3	Brennan Sand Co., Severn River, ¼ mile below Whitney's Landing	Molding or Core	.....	.12	.10	13.16	60.80	10.34	1.50	1.54	.02	.04	11.70	99.32	344	0	......	150.83
4	Brennan's Sand Co., Severn River, ¼ mile below Whitney's Landing	Core......	.....	2.02	2.42	28.34	48.12	7.90	1.70	3.28	.56	.40	5.18	99.92	8	0	......	241.55
5	J. Funkhouser, 3 Miles N. of Hancock....	Molding..	.....	2.20	2.96	11.44	25.38	15.44	5.40	9.50	2.54	.20	24.44	99.50	240	4.2 5.0 6.8 9.8	121.8 131.6 126.7	27.69 38.63 42.65 37.03
6	A. A. Foltz Rock Forge..	Core......	.....	.....	.....	.52	64.08	22.52	3.00	3.24	.04	.02	6.45	99.87	72	0	......	116.97

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 20	On 270	Through 270	Clay Substance	Total				
236	Saginaw......	....	.....	.....	.07	1.35	65.36	30.86	1.49	.19	.14	.17	.....	99.63	40	0	......	112.0
700 (501)	Cheboygan....	....	1.00	3.04	2.38	30.92	57.10	1.54	.24	.12	.14	.54	3.12	100.14	104	4.2 5.7 7.3 8.7 10.0	...... 63.0 69.0 74.0 Too	467.0 398.0 326.0 246.0 wet
701 (502)	Black Lake District.....	....	.....	.02	.12	3.72	64.66	27.74	1.72	.22	.24	.42	.98	99.84	104	2.5 3.7 4.9 7.5 9.4	.... 83. 86. 90.	205. 143. 162. 134. 117.
702 (503)	S. of Onaway..	....	.....	1.64	1.64	9.10	30.08	20.14	5.78	2.74	3.46	8.52	7.94	100.04	504	4.1 6.2 8.2	112. 120. 114.	42. 58. 49.
703 (504)	Bigelow.......	....	.....	.06	.38	8.52	52.70	24.62	5.12	1.64	1.54	3.08	2.06	99.72	104	2.5 3.9 5.9 7.6	Too 84. 90. 88.	dry 151. 128. 115.
704 (505)	Lewiston......	....	1.26	5.56	3.26	18.14	54.88	11.04	1.42	.32	.28	.54	2.82	100.12	176	2.5 3.9 5.7 7.9 9.4	Too 80. 85. 80.	dry 253. 235. 178. 162.
705 (506)	Bear Lake, Oscoda County	....	.....	.16	.27	4.57	60.81	30.10	2.65	.45	.25	.44	.....	99.70	40	0	......	126.
706 (507)	Luzerne.......	....	.....	.04	.08	8.06	57.72	24.24	4.98	1.56	1.24	.70	1.74	100.36	76	1.9 3.8 5.8 7.5 8.0	...... 75. 87. 87. Too	167. 198. 173. 156. wet
707 (509)	Alpena Co.....	....	.....	.....	.....	.45	31.52	53.73	10.75	2.38	.79	.23	.....	99.85	40	0	......	80.
708 (510)	Lachine.......	....	.....	.03	.43	13.50	53.99	27.49	2.29	.71	.72	.70	.....	99.86	172	0	......	134.
709 (511)	Alpena........	....	1.98	5.78	2.68	6.98	24.68	12.92	5.66	2.76	4.04	9.16	22.96	99.60	936	4.3 6.4 8 4	174. 207. 204.	21.8 33. 34.
710 (513)	Spruce........	....	1.20	3.96	1.90	7.00	31.54	13.34	5.38	2.62	2.98	7.80	22.48	100.20	872	4.9 6.2 8.2	193. 207. 194.	80. 93. (1)25.8
711 (516)	Edwards.......	....	.32	.18	.20	2.38	63.00	23.12	5.60	1.32	.70	.74	2.40	99.96	204	1.6 2.0 3.9 5.8 7.5	...... Too dry 83. 86. 80.	193. 178. 167. ....
712 (518)	Billings.......	....	.....	.06	.16	5.64	58.44	23.10	4.80	1.22	.92	.52	5.04	99.90	440	1.4 4.4 5.9 8.1 10.3	.... 84. 86. (2)91.	212. 173. 154. 133. 80.
713 (519)	Section 28, T16N, R1E	....	.....	.....	.02	2.22	60.52	28.94	5.78	.78	.24	.19	1.32	99.96	104	3.8 6.0 7.5 9.4	...... 78. 84. (2)87.	212. 178. 156. 133.
714 (520)	Midland.......	....	.....	.....	.02	1.56	50.18	38.18	6.27	2.08	.92	.17	.....	99.98	.....	0	......	80.
715 (521)	Vassar........	Core....	.....	.....	.01	.16	7.39	54.66	24.84	8.75	3.42	.54	.....	99.77	.....	0	.....	56.
716 (522)	Tuscola.......	....	.....	.....	.04	.36	6.72	19.88	22.58	23.36	19.06	6.26	1.74	100.00	104	2.3 3.9 5.9 7.9 10.2 11.0	.... 104. 109. 115. 110.	42. 62. 55. 49. 40. ......

(1) Probably too wet. (2) Too wet.

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
717 (523)	Juniata........	Core.....	.....	.....	.....	.10	8.06	46.03	32.76	9.83	2.80	.23	.....	99.81	104	0	......	55.
718 (524)	Silverwood....	....	1.70	.82	1.30	7.46	57.90	20.90	3.96	1.24	.84	.82	3.09	99.98	208	3.9 5.9 8.0 9.9	...... 80. **88.** 87. (1)	**226.** 193. 173. 133.
719 (525)	St. Clair......	....	.....	.06	.40	5.06	43.86	27.86	10.76	5.14	4.18	1.24	1.42	99.98	240	1.9 3.9 6.1 8.0 10.1	.... 88. 90. **91.**	117. **146.** 134. 122. Too wet
720 (526)	St. Clair......	....	.....	.03	.03	1.55	58.65	34.12	4.29	.58	.28	.30	.....	99.77	72	0	......	105.
721 (527)	Branch........	....	.60	5.20	6.24	21.66	37.56	16.86	3.00	.68	.66	1.20	6.50	100.22	744	2.5 4.5 6.3 8.4	Too **154.** 106. 94.	dry **178.** 156. 138.
722 (528)	Cass Co.......	....	.36	.90	.76	3.64	31.98	24.98	9.92	4.64	4.62	6.52	11.62	99.94	872	2.5 4.3 6.4 8.2	Too **161.** 130. 117.	dry **62.** **62.** 58.
723 (529)	Section 12, T8S, R14W.	....	.52	.64	.68	7.18	51.62	24.80	6.98	1.66	.76	.62	4.28	99.76	504	2.5 4.3 6.2 8.2	Too **100.** 91. 89.	dry **146.** 133. 177.
724 (530)	T7S, R21W, Berrien Co...	....	.....	.01	.01	.19	24.12	52.75	16.35	4.53	1.35	.50	.....	99.81	72	0	......	67.
725 (531)	Section 15, T6S, R19W. Berrien Co...	....	.36	.72	.68	5.66	46.46	15.94	2.92	.80	.96	4.10	21.14	99.74	2204	5.1 6.8 9.1	263. **295.** 278.	62. **80.** 58.
726 (532)	Section 24, T3S, R18W.	....	.....	.22	.16	.68	5.72	8.02	10.48	9.00	9.12	11.86	44.66	99.92	2736	6.9 9.1 11.8 14.0	244. 288. **350.** Too	17.9 **33.** 27. wet
727 (533)	Section 24, T3S, R18W.	Molding Sand...	.....	.06	.10	2.02	86.90	7.34	1.22	.26	.18	.26	1.72	100.06	204	3.6 5.7 7.7 10.0	68. 69. **72.** Too	358. **398.** 275. wet
728 (534)	Section 32, T6S, R12W, St.Joseph Co.	....	1.44	7.28	5.60	19.92	49.32	8.78	1.30	.29	.22	.54	5.28	99.97	536	2.5 3.2 4.0 5.8	Too **157.** 117. 90.	dry **313.** 287. 235.
729 (534a)	Section 18, T6S, R7W, Branch Co...	....	1.22	4.82	2.16	6.30	16.80	12.16	5.06	3.66	3.46	8.04	36.02	99.70	1536	6.8 8.9 10.9 13.0	211. 266. **345.** Too	8.5 21.8 **80.0** wet
730 (535)	South of N. Adams......	....	1.92	5.36	2.28	4.22	11.44	8.04	5.80	3.76	6.76	19.34	31.16	100.08	872	4.8 6.3 8.4 10.0	227. **265.** 226.	3.7 7.2 **21.2** 2.4
731 (536)	....		.....	.....	.10	3.74	38.24	25.14	7.46	1.78	.82	.50	2.34	80.12	236	1.5 3.9 5.8 8.0 10.0	...... 82. 82. **88.** Too	**162.** 156. 142. 117. wet
732 (2003)	Broomfield Twn., Isabella Co..	....	.....	.....	.01	.03	4.00	52.34	26.00	9.21	5.00	3.12	.....	99.71	72	0	......	48.
733 (2004)	2 Miles N. E. Mt. Pleasant.	....	.68	2.10	1.64	7.06	50.20	20.28	8.20	2.22	1.40	1.42	4.60	......	104	2.1 3.8 5.7 7.9 10.0	...... 86. 90. **91.** Too	87. **117.** 105. 105. wet

(1)Too wet.

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
734 (2005)	8 Miles N. Barryton....	....	.42	2.16	.54	2.28	44.06	25.96	6.60	2.18	1.56	2.02	12.04	......	644	2.5 2.9 5.0 6.1 8.2	...... 148. 136. 105. 98.	105. 133.(1) 117. 93. 72.
735 (2006)	Sylvan Twp., Osceola Co..	....	.....	.14	.08	1.63	66.50	27.30	2.89	.61	.37	.27	.....	99.79	40	0	......	140.
736 (2009)	1 Mile S. Lake City...	....	.68	.76	.92	8.44	45.48	13.72	3.38	1.20	1.24	2.48	21.40	99.70	872	(2)4.2 6.1 8.3	196. 205. 148.	87. 80. 72.
737 (2010)	Roscommon Twp., Roscommon Co.	....	.....	.04	.20	4.36	43.82	26.78	15.76	5.00	2.14	.76	1.32	100.18	104	1.5 3.1 4.1 5.8	...... 83. 91. 90.	108. 105. 93. 93.
738 (2011)	Denton Twp., Roscommon Co..........	....	.....	.12	.20	4.64	43.34	33.12	9.18	3.46	2.38	1.80	1.68	99.92	208	0 2.1 4.1 6.0 7.9	.... 91. 93. 95.	58. 108. 105. 105. (3)93.
739 (2012)	Grayling......	....	.....	.54	.72	11.40	71.84	8.62	1.02	.18	.20	1.78	3.56	99.86	40	3.1 3.9 5.9	76. 83. 79.	219. 235. 219.
740 (2013)	Otsego Twp. Otsego Co...	....	.....	.29	.44	14.83	72.08	10.35	1.53	.24	.09	.16	.....	100.01	40	0	......	192.
741 (2014)	1½ Miles S. Vanderbilt Station......	....	.08	1.60	1.20	12.78	61.52	15.18	3.44	1.10	.76	.88	1.50	99.94	104	1.3 2.0 3.2 3.9 5.7 7.0	...... Too ...... 79. 83. 82.	205. dry 219. 212. 190. 167.
742 (2014 A)	4 Miles N. W. Wolverine...	....	.....	.01	.05	4.31	66.84	21.33	4.53	1.27	.77	.61	.....	99.72	40	0	......	118.
743 (2015)	Mullet Lake Station......	....	.....	.05	.11	9.66	71.99	16.26	1.41	.13	.07	.25	.....	99.73	72	0	......	170.
744 (2016)	Mackinaw City	....	.....	.02	.24	4.52	74.00	16.84	2.04	.22	.18	.34	1.72	100.12	104	3.2 3.8 5.7 8.0	...... 77. 79. 78.	219. 235. 198. 167.
745 (2017)	Mackinaw City	....	.09	.12	.30	2.12	44.34	38.22	9.04	2.49	1.53	1.40	.....	99.65	72	0	......	74.
746 (2018)	5 Miles N. St. Ignace...	....	.....	.....	.....	.39	61.68	32.07	5.09	.40	.07	.20	.....	99.90	104	0	......	117.
747 (2019)	3½ Miles from Hessel.......		.....	.02	.30	12.70	53.98	21.96	6.82	2.04	.98	.30	1.08	100.18	8	1.9 3.8 5.7 8.0	...... 81. 84. (3)91.	178. 193. 162. 133.
748 (2020)	13 Miles S. Soo	....	.20	1.08	.42	3.12	28.78	31.68	17.44	7.26	4.58	2.18	3.28	100.02	....	1.9 3.3 4.1 5.9 7.4	.... 96. 98. (3)99.	58. 87. 79. 79. 62.
749 (2021)	3 Miles S. E. Brimley......	....	.08	.72	.96	3.90	17.30	23.34	17.90	13.38	13.02	3.92	5.48	100.00	240	4.3 6.2 8.3	95. 110. 108.	44. 49. 47.
750 (2022)	Kinross Twp., Chippewa Co.	....	.....	.....	.05	1.30	33.13	36.15	17.19	6.82	3.84	1.43	.....	99.91	72	0	......	60.
751 (2023)	Trout Lake Twp. Chippewa Co	....	.....	.72	.92	6.82	60.64	25.10	1.68	.26	.20	.56	3.18	100.08	204	2.6 5.9 7.9 10.1	...... 86. 89. 84.	193. 154. 133. 122.
752 (2024)	Trout Lake, Twp., Chippewa Co.	....	.....	.....	.....	.11	16.23	47.90	25.97	6.63	2.57	.41	.....	99.82	72	0	......	62.5
753 (2025)	Hudson Twp., Mackinaw Co.	....	.....	.48	1.00	21.78	61.36	9.86	1.60	.50	.46	.58	2.50	100.12	104	3.1 4.0 5.1 6.8	73. 79. 76.	264. 275. 257. 253.

(1) Too dry. (2) Almost too dry. (3) Wet.

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
754 (2026)	½ Mile S. Dollarville...	....	.....	.01	.14	3.33	49.76	28.75	10.23	3.93	2.54	1.17	.....	99.86	40	0	......	83.
755 (2027)	6 Miles S. E. Seney........	....	.....	.....	.....	.02	3.86	31.52	32.03	15.74	12.73	3.90	.....	99.80	104	0	......	42.
756 (2028)	11 Miles N. Seney........	....	.....	.01	.02	.42	22.24	50.81	17.60	5.17	2.81	1.05	.....	100.13	236	.....	.....	.....
757 (2029)	6½ Miles N. Seney........	....	.36	4.92	6.46	28.44	47.42	8.56	2.08	.44	.28	.36	.64	99.98	104	1.6 3.9 5.4 7.7	...... 69. 73. 74. (1)	341. 326. 300. 253.
758 (2030)	12 Miles N. E. Munising....	....	.....	.24	.28	3.34	42.84	34.10	10.96	2.98	1.86	1.10	2.20	99.90	272	1.7 3.2 4.0 5.8 8.1	.... 87. 91. 88.	105. 133. 133. 117. 115.
759 (2031)	4 Miles E. Munising....	....	.13	1.03	1.40	10.22	62.07	15.07	4.34	1.75	1.51	2.04	.....	99.56	72	0	......	80.2
760 (2031-A)	West of Munising..	....	.87	3.67	2.78	19.08	60.83	9.60	1.99	.44	.29	.43	.....	99.98	40	0	......	150.
761 (2032)	3 Miles N. W. Scandia......	....	.....	.....	.11	3.97	42.67	23.85	13.85	7.37	6.01	2.09	.....	99.92	8	0	......	56.
762 (2033)	Eagle Mills....	....	.10	1.84	2.53	8.83	46.84	21.22	9.23	3.90	3.00	2.27	.....	99.76	8	0	......	64
763 (2034)	Chassell Twp. Houghton Co.	....	.40	2.24	1.92	7.10	27.78	15.36	9.32	5.84	6.46	9.48	13.72	99.62	808	2.9 4.2 6.2 8.5	155. 173. 169. 149.	...... 31. 55. 36.
764 (2035)	2 Miles W. Houghton....	....	.....	1.16	1.10	7.08	43.96	19.56	6.12	3.28	4.40	9.40	3.54	99.60	236	4.0 5.8 8.0 10.1	98. 99. 99. 99.	79. 79. 87. 72. (1)
765 (2037)	1 Mile S. W. Parnsdale...	....	1.30	2.32	1.74	6.54	27.00	14.88	9.02	5.68	7.50	12.00	11.76	99.74	140	3.0 4.0 5.9 7.8 9.8	120. 139. 136. 124.	17.3(2) 21. 30. 33. 30.
766 (2038)	Elm River Twp Houghton Co.	....	.....	.14	.40	8.34	69.62	13.52	3.81	1.38	1.29	1.38	.....	99.88	72	0	......	127.
767 (2039)	1 Mile S. of Paulding....	....	.....	.49	.68	4.62	49.13	26.04	10.25	3.67	2.64	2.20	.....	99.72	136	0	......	62.
768 (2040)	¾ Mile W. of Gogebic Sta.	....	.....	.30	1.81	21.50	61.25	9.62	2.26	.64	.59	1.65	.....	99.62	40	0	......	130.
769 (2041)	1 Mile E. of Watersmeet..	....	.19	3.95	3.36	14.02	59.75	13.46	3.19	.82	.53	.72	.....	99.99	40	0	......	126.
770 (2042)	1 Mile S. of Crystal Falls	....	.....	.98	1.12	6.28	51.06	20.30	7.98	2.84	2.48	4.74	2.36	100.14	40	3.6 5.8 7.9 10.0	87. 88. 92. 86.	105. 117. 93. 93.
771 (2043)	5 Miles N. Iron Mt......	....	.92	.80	.24	.54	4.80	11.44	13.70	15.22	25.70	21.06	5.34	99.76	204	4.1 6.1 8.0 9.9 12.0	...... 125. 139. 141. 144.	19. 21. 19.5 18.4 13.4
772 (2044)	5 Miles S. Ford River..	....	.....	.14	.10	5.92	89.05	3.45	.30	.12	.15	.68	.....	99.91	40	0	......	197.
773 (2045)	3 Miles E. Rapid River.	....		.02	.43	28.11	55.40	8.16	3.74	1.65	1.48	.94	.....	99.93	8	0	......	162.
774 (2047)	4 Miles from Engadine....	....	.....	.....	.01	3.20	76.62	18.92	1.12	.10	.05	.05	.....	100.07	40	0	......	141.
775 (2048)	Hendricks Twp., Mackinac Co......	....	.07	.77	2.68	28.43	59.40	7.22	.76	.12	.11	.38	.....	99.94	72	0	......	231.
776 (2052)	1½ Miles N. W. Boyne City..	....	.....	.02	.08	2.54	61.05	31.33	4.25	.36	.11	.17	.....	99.91	72	0	......	120.
777 (2053)	3 Miles W. Elmira.....	....	.....	.10	.37	4.85	55.30	26.18	7.23	2.40	1.65	1.93	.....	100.01	72	0	......	78.5

(1) Too Wet. (2) Almost too dry.

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
778 (2054)	¾ Mile N. E. Simmons....	....	.....	.76	1.25	24.30	68.60	3.88	.53	.10	.10	.29	.....	99.81	8	0	......	279.
779 (2055)	1 Mile N. Kalkaska....	....	.....	.35	.47	8.99	73.80	12.94	2.20	.35	.23	.51	.....	99.81	104	0	......	147.
780 (2056)	2 Miles S. Sharon......	....	.04	.31	.62	9.95	65.33	18.22	3.77	.80	.50	.48	.....	100.02	40	0	......	128.
781 (2060)	Green Lake Twp., Grand Traverse Co.	....	.09	.47	.48	15.63	73.72	7.94	.97	.15	.09	.33	.....	99.67	40	0	......	189.
782 (2061)	1 Mile W. Honor.......	....	.....	.....	.10	12.80	83.92	2.70	.15	.02	.01	.14	....	99.84	40	0	......	260.
783 (2063)	6 Miles N. E. Bear Lake.....	....	.....	.28	.42	5.84	46.56	27.46	10.98	3.76	2.26	1.24	1.22	100.02	136	1.5 3.9 5.8 7.4 9.5 11.6	.... 92. 97. 101. 93	119. 128. 105. 93. 67. 62.
784 (2065)	Stronach Twp. Manistee Co.	....	.20	2.30	3.04	20.12	65.62	6.60	.78	.14	.14	.26	.90	100.10	8	2.8 3.9 5.8 7.0 8.5	...... 67. 71. 74. 66.	341. 313. 270. 235. 235.
785 (2066)	1 Mile E. Ludington...	....	.....	.....	.03	5.35	78.12	12.59	2.89	.77	.31	.17	....	100.08	72	0	......	145.
786 (2067)	1½ Miles N. W. Walhalla....	....	.....	.....	.04	4.13	58.23	20.63	8.08	4.25	3.19	1.04	.....	99.59	8	0	......	77.
787 (2100)	1½ Miles S. W. Plymouth...	....	1.86	2.50	2.09	8.58	63.48	14.76	2.48	.60	.64	1.16	1.56	99.66	72	1.5 2.3 3.9 5.9 7.7 10.5	.... 70. 74. 79. 78.	198. 235. 243. 235. 198. 156.
788 (2102)	2½ Miles S. W. Dundee......	....	.28	.30	.42	3.74	28.14	24.90	17.70	9.26	6.96	3.48	4.34	99.52	240	4.1 5.8 8.1 10.4	100. 103. 105. 107.(1)	62. 67. 62. 62.
512	Alpena.........	....	.00	.41	4.50	33.73	8.74	4.58	7.63	2.67	8.46	.00	28.92	99.64	304	2. 4. 6.4 9.1 12.8	84.5 161.4 158.9	2.08 7.31 9.59 10.10 7.62
514	5 Miles W. Black River.	....	.....	.....	.84	2.32	55.74	13.10	4.15	8.28	.37	.25	14.67	99.72	144	1.6 4.0 6.8 9.7	92.3 128.9 120.1	35.19 64.55 65.93 50.09
515	Iosco.........	....	.....	.49	1.74	9.53	39.66	6.14	2.23	3.72	.13	.07	36.25	99.96	1672	4.5 6.46 10.3 Too	214.24 300.00 341.01 wet	115.22 212.64 65.71
517	Center Section 16, T 17N., R1 E, Gladwin......	....	.....	.....	.....	.27	69.70	19.59	4.22	4.03	.....	.....	2.18	99.99	40	Dry	......	119.08
2046	½ Miles S. E. Cook's Mill..	....	.....	.....	.....	.08	14.20	38.20	14.97	23.52	.65	1.11	7.02	99.75	76	2.1 3.9 5.9 6.4	...... 84.9 98.5 92.0	59.6 67.2 66.6 61.0
2049	3 Miles E. Gross Village	....	.....	.....	1.52	19.10	75.88	.69	.02	.....	.....	.....	2.83	100.04	76	Dry	......	399.36
2050	1½ Miles center Pellston.....	....	.....	.....	.20	5.02	77.28	11.77	2.94	.02	.....	.....	2.62	99.85	72	Dry	......	164.22
2051	Little Traverse Bay.........	....	.....	.....	.11	7.67	77.32	10.16	2.49	1.49	.04	.04	.464	99.784	40	Dry	......	221.59
2057	1 Mile N. Kingsley....	....	.....	.....	.45	8.25	76.43	9.90	1.91	1.32	.10	.....	1.56	99.92	8	Dry	......	146.04
2058	½ Mile N. Northport...	....	.....	.....	.15	4.29	86.94	5.67	.48	.23	.....	.....	2.24	100.00	140	Dry	......	230.33

(1) Wet.

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
2059	½ Miles S. Grand Traverse	....	....	1.05	4.75	26.19	66.03	1.39	....	....	....	....	.49	99.90	40	Dry	....	296.56
2062	South Frankfort	....	....	....	....	1.44	86.35	7.69	.64	.47	....	....	3.18	99.77	40	Dry	....	207.54
2068	Lake Twp., Lake Co.	....	....	.34	1.38	14.01	70.59	8.96	1.77	1.33	....	....	1.53	99.91	140	Dry	....	170.47
2069	....	....	....	.85	2.30	24.34	62.55	6.13	1.11	.57	....	....	2.17	100.02	40	Dry	....	202.22
2070	Wilcox Twp., Newaygo Co.	....	....	....	....	2.69	52.88	24.29	8.44	10.43	.55	.02	.61	99.91	140	Dry	....	117.98
2071	2½ Miles N. Montague	....	....	....	.40	7.65	66.09	14.65	3.81	3.29	.24	.10	3.41	99.64	272	Dry	....	118.65
2072	2.7 Miles W. Nunica	....	....	....	....	2.60	65.58	20.89	5.93	3.99	.13	....	.82	99.94	40	Dry	....	122.57
2073	2½ Miles S. Muskegon Hts.	....	....	.78	7.97	78.31	8.13	1.17	.64	....	....	....	2.72	99.72	104	Dry	....	221.48
2074	1.8 Miles from Agnew	....	....	....	....	1.15	67.69	21.07	5.36	3.62	....	....	1.06	99.95	40	Dry	....	136.01
2075	3 Miles N. Belding	....	....	.37	.94	13.24	72.41	6.95	1.54	2.80	....	....	1.62	99.96	40	Dry	....	214.92
2076	2 Miles W. Mecosta	....	....	.30	1.67	14.84	75.13	4.88	.70	.69	....	....	1.55	99.76	40	Dry	....	282.52
2077	½ Mile S. Newaygo	....	....	3.88	7.28	25.65	55.47	4.71	.35	.46	.01	....	2.13	99.94	72	Dry	....	150.69
2078	2 Miles N. W. Holton	....	....	....	....	1.90	82.09	11.83	1.64	.51	....	.00	1.95	99.92	40	Dry	....	147.58
2079	3 Miles N.W. Hart	....	....	.68	1.55	11.09	62.97	11.74	2.65	3.88	.25	.07	5.08	99.96	72	Dry	....	116.66
2080	Grand Rapids Twp., Kent	....	....	1.06	1.73	17.05	76.06	2.91	.20	.08	....	....	.86	99.95	8	Dry	....	213.91
2081	4 Miles S. Brighton	....	....	....	.19	.69	39.29	32.25	11.53	10.79	.35	.42	4.47	99.98	272	Dry	....	86.83
2082	1 Mile N. Brighton	....	....	.18	.21	.94	67.16	21.39	4.57	2.47	....	....	2.97	99.89	104	Dry	....	113.65
2083	Mt. Morris Twp., Genessee Co.	....	....	.41	.98	2.47	32.04	30.51	11.59	15.41	.55	.09	5.91	99.96	72	Dry	....	48.57
2084	3½ Miles W. Saginaw	....	....	....	....	1.82	26.26	16.68	9.02	34.55	2.21	2.18	7.28	100.0	72	4.8 5.8 6.2 7.4	107.4 110.7 104.5	40.4 45.2 42.2 35.8
2086	2 Miles W. Amadore	....	....	1.23	3.17	13.41	15.97	14.92	10.83	24.81	.84	.10	14.68	99.96	72	2.1 4.1 6.3 6.8	84.0 106.8 92.9	38.2 47.3 49.2 47.0
2087	2 Miles N. Amadore	....	....	....	.16	2.28	35.61	30.17	12.73	14.34	.07	.04	4.58	99.98	104	Dry	....	53.19
2088	....	Core	....	....	.08	1.56	35.76	28.17	11.68	15.36	.15	.00	7.02	99.78	136	Dry	....	60.73
2089	Tekonsha Twp., Calhoun Co.	....	....	1.16	3.31	11.86	51.24	13.34	4.71	8.10	.14	.07	6.09	100.02	104	Dry	....	94.92
2090	1½ Miles N. W. Athens	....	....	1.76	5.07	22.73	51.26	6.80	1.51	2.82	.10	.02	7.96	100.03	272	Dry	....	92.30
2091	2 Miles W. Matawan	....	....	.44	4.53	36.59	44.05	1.78	.23	.21	....	....	12.19	100.02	272	Dry	....	73.93
2092	1 Mile W. Plainwell	....	....	....	.17	10.98	71.08	12.54	2.41	.89	....	....	1.80	99.87	104	Dry	....	139.26
2093	5 Miles N. Kalamazoo	....	....	4.84	7.92	16.34	41.85	11.43	4.00	7.55	.94	1.15	3.95	99.97	72	Dry	....	27.08
2094	1½ Mile E. Augusta	....	....	1.05	3.25	36.02	56.48	1.48	.07	.06	.01	.03	1.56	100.01	72	Dry	....	283.48
2096	Baltimore Twp., Barry Co.	....	....	....	....	.17	1.29	2.05	2.78	42.48	6.13	7.43	37.68	100.01	504	1.7 4.1 5.8 8.1	89.47 128.60 130.21 127.48	12.06 17.19 18.32 15.34
2097	1 Mile N. Alto	....	....	....	.08	.68	68.18	23.50	4.29	2.00	.05	.04	1.05	99.87	104	Dry	....	121.41
2098	Grand Rapids	....	....	....	.23	6.96	87.05	4.45	.47	.31	.06	....	.44	99.97	40	Dry	....	258.88
2099	10 Miles S. Grand Rapids	....	....	....	.07	2.80	63.88	19.07	5.89	6.48	.14	.06	1.49	99.88	8	Dry	....	96.46

MICHIGAN

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
3000	2 Miles S. W Allegan					.15	.62	.93	1.66	29.42	7.16	3.87	56.15	99.96	640	3.8 6.2 8.0 9.9 12.5	137.41 171.91 188.53 167.60	2.68 4.58 6.21 7.10 6.18
3001	1½ Miles E. Pullman				.03	.54	44.88	28.94	10.62	11.68	.89	.14	2.05	99.77	72	Dry	......	94.60
3002	5 Miles W. Pullman				.09	.06	4.18	23.97	12.62	37.75	4.49	5.37	11.46	99.99	608	1.1 2.3 4.4 6.3 8.3	61.14 120.00 116.52	...... 25.67 31.58 34.57 31.28
3004	6 Miles N. Saugatuck					3.06	60.37	22.19	6.45	5.54	.16	.03	1.81	99.61	72	Dry	......	110.86
3005	3 Miles E. Hartford				.07	.36	8.41	12.15	9.28	29.51	.29	1.93	37.93	99.93	876	1.9 4.7 6.3 8.4	125.30 175.88 146.40	10.98 28.35 29.24 28.69
3006	1 Mile N. W. Berlamont				.12	.19	1.23	1.02	.55	2.18	1.33	7.30	86.02	99.94	1936	7.2 8.8 9.3 11. 11.9	197.84 226.29 225.72	1.42 1.61 2.19 3.39 3.12
3007	2 Miles E. Lacota					.32	56.49	27.34	7.39	6.69	.05	.19	1.36	99.83	72	Dry	......	92.73
3008	½ Mile S. Burnips			.27	.45	3.29	32.72	13.32	8.33	26.27	1.60	2.05	11.64	99.94	404	1.9 4.3 5.7 8.5	100.2 122.38 113.4	19.18 36.91 37.76 31.19
3009	1 Mile E. Middleville		.90	2.23	2.63	9.19	43.36	14.81	4.87	6.52	.22	.04	15.17	99.94	772	Dry 1.9 4.1 6.1	...... 149.6 167.1 110.3	38.92 100.64 93.92 79.95
3010	4½ Miles W. Hastings			1.04	1.42	5.60	34.48	18.18	8.41	15.70	2.25	3.00	9.91	99.99	340	2.2 4.3 5.9 9.0	78.5 124.2 107.1	27.96 44.49 46.88 43.35
3011	1 Mile E Ceresco					.22	15.40	31.67	18.26	29.86	.32	1.47	2.77	99.97	140	Dry	......	45.58
3012	1 Mile N. Urbandale			.60	.75	2.59	22.15	15.14	6.42	14.62	.92	.14	36.69	100.02	640	2.0 4.4 6.2 8.4 10.4	87.9 151.4 150.6	...... 10.76 20.99 24.26 17.09
3013	3 Miles S. E. Albion			.24	.66	1.62	36.68	26.65	10.86	.68	15.16	.13	7.32	100.00	272	Dry	......	76.12
3014	1 Mile E. Jackson City		2.38	2.30	2.81	6.77	24.97	10.80	5.31	11.58	1.06	.69	31.27	99.94	808	2.0 4.2 6.5 7.4 10.0	109.4 203.8 189.7	...... 11.39 37.27 54.12 13.44
3015	2 Miles W. Chelsea		1.14	4.36	13.95	52.98	19.41	1.29	.33	.77	.13	.20	5.41	99.97	276	Dry	......	227.61
3016	3 Miles N. Marshall		.77	2.95	3.06	10.51	53.82	15.03	4.41	4.17	.17	.09	4.90	99.88	372	Dry	......	99.32
3017	3 Miles S. E. Jackson			.52	1.26	2.26	4.89	10.17	14.08	53.30	4.28	1.80	7.43	99.99	236	Dry	......	23.74
3018	3 Miles S. E. Norwell		6.18	13.67	10.43	24.28	25.78	5.07	1.66	3.29	.69	.68	8.15	99.88	372	Dry	......	96.90

NEW JERSEY

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
501	Millville.......	Coarse Molding Gravel..	.64	28.78	20.98	16.16	20.38	3.06	.60	.20	.28	.60	8.10	99.84	240	2.5 3.8 5.8	(1) **132** 80	...... **950.** 780.
502	Millville	Sharp Silica Steel Molding Sand....	.....	3.12	12.28	49.82	24.14	2.56	.54	.26	.24	.40	6.90	100.26	124	2.2 2.8 3.9 5.9 7.6	119 **158** 107 80	492. **780.** 650. 650. 55.
503	Millville.......	Molding Gravel with Strong bond....	1.18	13.00	16.18	20.34	25.94	1.74	.66	.26	.30	.46	20.14	100.20	....	5.0 7.0 8.4	208 **352** 253	463. **480.** 291.
504	Millville.......	Molding Sand with Strong bond...	.....	.02	.14	.78	19.62	36.82	18.94	3.42	1.96	2.16	15.92	99.78	1176	3.0 4.1 6.1 8.2	183 (1) **268** 248 189	55. 62. **80.** 55.
505	Millville.......	Molding Gravel with Strong bond....	1.26	10.04	14.30	28.96	22.82	2.66	1.08	.42	.36	.62	17.84	100.36	....	4.0 6.0 8.0	149 **286** 223	275. **584.** 225.
506	Dorchester....	Molding Sand....	.....	.08	.58	2.16	29.18	33.54	14.62	3.26	2.40	2.42	11.52	99.76	544	2.8 3.9 6.0	160 **182** 132	72. **93.** 80.
507	Belle Plain....	Molding Gravel..	.48	5.74	7.42	.18	56.90	7.00	1.46	.52	.48	.84	18.96	99.98	744	4.4 6.3 8.3 10.2	(1) **376** 365 280	80. **176.** 176. 79.
508	Belle Plain....	Molding Gravel..	.58	11.08	12.76	4.94	45.34	3.30	.86	.36	.30	.54	19.98	100.04	944	4.5 6.2 8.4 10.3	187 (1) **380** 366	105. **217.** 217. 105.
509	Clayville......	Molding Gravel..	3.48	16.90	17.56	31.80	11.00	1.50	.70	.34	.32	.72	15.76	100.08	408	4.1 6.3 8.1 9.5	143 **256** 214	341. 398. **492.** 326.
510	Clayville......	Molding Gravel..	2.82	18.96	23.66	3.94	33.54	1.54	.68	.28	.28	.60	11.66	99.96	376	3.9 5.8 7.7	176 (1) **189** 115	780. **950.** 610.
511	Landisville....	Molding Gravel..	2.04	6.70	11.60	3.14	55.26	3.38	.66	.22	.28	.54	16.36	100.18	408	3.3 4.1 6.0	(1) **271** 248	253. **398.** 358.
512	Cedar Lake....	Steel Molding Sand....	.....	.02	.26	1.18	29.04	28.46	13.08	3.48	2.28	2.96	19.06	99.82	944	3.9 6.0 8.1	(1) **278** 224	44. **80.** 62.
513	Folsom.........	Steel Molding Sand....	.46	4.16	4.94	.06	56.60	16.82	3.96	.84	.56	1.26	10.34	100.00	376	2.9 3.9 5.8	(1) **175** 147	154. **176.** 154.
514	Newtonville...	Core Gravel	2.16	10.46	12.88	21.64	29.04	2.80	.92	.38	.38	.62	18.74	100.02	536	4.4 6.3 7.7	(1) **332** 244	178. **492.** 300.
515	Richland......	Molding Gravel	1.94	11.24	12.74	.90	24.72	3.40	1.00	.44	.48	1.34	21.82	100.02	944	4.5 6.2 8.4	(1) **347** 318	85. **275.** 253.
516	Downer.......	Steel Sand	.....	.22	.42	.06	38.36	31.70	8.34	1.26	.70	1.18	17.32	99.56	944	4.1 6.0 8.0	(1) **292** 212	93. **105.** 55
517	Downer.......	Core Sand	.....	.01	.02	.08	69.66	26.42	2.71	.46	.26	.49	.....	100.11	76	0	......	138.
518	Blenheim......	Fine Molding Sand....	.....	.16	.10	.02	.72	.68	2.62	13.92	33.46	28.76	19.42	99.86	1336	3.7 6.0 8.2 10.3	...... 158 164 **166**	9.7 12.2 11.4 **11.4**(2)
519	Mt. Holly.....	Molding loam....	.....	.02	.74	.14	29.64	21.86	14.30	6.54	4.20	4.90	17.36	99.70	1536	4.5 6.3 8.7	193 **258** 211	42. **62.** 49.

(1) Too dry. (2) Too wet.

NEW JERSEY

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Adsorption	Water Per Cent	Bond Strength	Permeability
520	Lumberton	Lumberton loam	.....	.50	1.72	.10	19.76	14.86	12.50	10.34	11.42	9.76	18.96	99.92	....	5.0 7.0 8.0	208 (3) 225 223	23. 28. 25.
521	Smithville.....	Lumberton loam.	.....	.96	3.46	.70	31.08	16.48	9.28	3.38	2.78	6.22	25.22	99.56	1704	6.7 8.6 11.8	270 308 201	49. 62. 30.
522	Mt. Holly.....	Lumberton loam.	.....	.18	1.00	.24	21.48	20.94	13.68	5.98	4.76	7.90	23.82	99.98	1872	5.3 6.8 8.8 11.9	...... 273 283 234	33. 38. 30. 14.7
523	Birmingham...	Not used.	.....	.38	3.08	4.26	34.64	16.34	11.24	5.84	5.00	3.80	15.32	99.90	1336	4.7 5.8 6.7 8.8	...... 283 294 267	58. 79. 67. 52.
524	Masonville.....	Lumberton loam.	.....	.08	1.08	.28	45.14	25.66	12.00	3.82	1.52	.34	9.84	99.76	....	3.0 5.0 8.0	(1) 278 175	97.7 107.0 69.5
525	Bridgeboro....	....	.60	1.70	3.46	1.22	49.70	18.48	10.10	4.24	2.16	1.04	7.22	99.92	576	3.4 4.3 6.1 8.4	178 163 119 110	93. 105. 80. 72.
526	Burlington....	....	.....	1.58	2.68	2.38	67.86	11.54	3.38	.80	.58	.98	8.52	100.30	544	3.0 4.1 6.1	137 (1) 173 119	193. 235. 219.
527	Perth Amboy.	Molding Sand....	.....	.06	.06	.04	39.74	35.78	10.84	3.82	2.32	1.80	5.66	100.12	176	2.2 3.7 5.8 7.6 10.3	(1) 95 92	88. 105. 105. 117. 93.
528	South Amboy..	....	.....	.72	.92	.76	43.56	24.36	10.92	4.54	4.40	4.70	4.84	99.72	272	2.5 3.7 5.7 7.9 10.0	66 (1) 96 96 91	72. 80. 93. 112. 62.
529	South Amboy..	Steel Sand	.....	.15	.83	10.86	77.74	8.73	.68	.19	.14	.22	.....	99.54	76	0	......	240.5
530	South Amboy.	Fine Molding Sand....	.....	.02	.28	.04	49.84	28.32	9.44	2.60	1.74	2.12	5.44	99.84	240	2.5 4.0 6.0 8.1	(1) 91 91 86	105. 133. 117. 117.
531	South Amboy.	Molding Gravel...	.....	1.98	7.88	31.36	36.98	3.26	1.80	.90	1.14	3.16	11.64	100.10	240	4.2 6.3 8.2 9.6	137 129 103	105 (4) 253. 275. 219.
532	South Amboy.	Molding loam....	.....	.44	.88	4.04	8.94	4.84	3.00	2.54	5.02	25.00	45.20	99.96	972	6.8 8.6 10.9 14.1 16.0	137 183 222 247 (2)	3.1 4.0 6.3 8.8 (2)
533	Perth Amboy.	Coarse Foundry Sand....	.....	3.48	15.90	34.56	28.54	4.04	1.94	.72	.74	.94	9.08	99.94	240	2.8 3.9 5.9 9.8	(1) 131 94	300. 550. 550. 326.
534	Flanders.......	Steel Sand	.....	4.02	5.44	17.20	33.20	15.38	8.20	3.28	2.54	4.48	6.36	100.10	76	2.7 3.7 5.7 7.7 9.1 10.2 11.2	82 85 86 93 ...... 95 (2)	85. 105. 133. 134. 146. 154. 93.
535	Hackettstown.	....	.....	.02	.14	6.54	41.36	22.10	11.96	5.60	4.92	4.56	2.36	99.56	76	4.0 5.9 7.9 10.1	74 79 85 90 (1)	151. 162. 162. 154.
536	Phillipsburg...	Molding loam....	.....	.....	.....	.44	35.30	21.28	11.62	6.18	6.92	9.52	8.46	99.72	240	3.4 4.2 6.0 7.8 9.8 11.6	(1) 118 117 115	49. 55. 58. 62. 55. ......

(1) Too dry. (2) Too wet. (3) Flawed. (4) Rather dry.

NEW YORK

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
231	See Footnote	Albany fine selected..	.....	.18	.10	.22	.44	.80	2.80	7.18	25.60	44.66	18.42	100.40	304	5.5 7.4 10.5	168 176 169	6.4 7.3 5.8
360	....	OOO-P...	.....	.16	.08	.54	3.70	1.98	1.88	3.90	18.10	47.40	22.12	99.86	576	6.3 7.8 10.2 11.9 14.3	171 187 185	6.3 7.2 7.7 8.8 6.0
209	....	OO strong	.....	.14	.06	.26	1.16	1.28	2.26	4.94	21.84	47.68	21.12	100.74	336	4.0 6.0 8.0 9.6 11.5	182 203 200	3.15 5.43 5.8 10.7 7.5
221	....	OO........	.....	.38	.16	.26	1.78	2.98	4.54	7.08	20.80	42.34	20.06	100.38	304	4.0 6.0 8.7 10.7	141 171 186 174	5.7 6.3 7.5 6.0
232	....	OO........	.....	.22	.20	.12	1.10	4.78	18.16	22.14	26.68	17.22	9.20	99.82	244	4.0 6.0 8.0 9.5	Too dry 133 123	18.4 21.0 22.0 21.8
249	....	OO open..	.....	.....	.06	.02	1.92	3.46	12.36	16.48	19.34	26.54	19.52	99.70	276	4.00 6.00 8.00 12.00	Too dry 172 172 169	6.7 8.2 9.4 8.8
253	....	OO strong	.....	.20	.12	.22	.62	1.28	5.56	8.74	19.14	37.34	27.00	100.22	336	5.00 7.4 9.6 12.2 13.9	185 200 199	2.6 3.7 4.9 7.2 6.0
254	....	OO........	.....	.26	.12	.32	.86	2.44	5.88	12.68	31.52	33.00	13.08	100.16	272	4.0 6.0 8.0 9.7 11.7 13.6	171 186 181	3.5 6.5 8.8 10.0 13.9 8.2
258	....	OO-J......	.....	.06	.12	.40	3.44	4.50	4.90	5.34	18.56	46.66	16.00	100.00	304	4.0 6.0 8.0	188 190 187	4.7 7.7 7.5
361	....	OO-P......	.....	.16	.22	.40	2.32	1.36	2.68	5.56	23.04	46.76	17.00	99.62	304	6.2 7.8 10.5 13.2	159 171 179 176	7.7 8.2 9.0 7.2
203	....	O strong..	.....	.04	.08	.20	1.30	3.16	7.58	10.86	27.50	34.58	14.68	99.98	244	4.0 6.0 8.0 9.4 11.9	196 190 182	6.7 9.8 10.3 11.8 7.9
207	....	O.........	.30	.38	.18	.30	2.12	4.92	8.50	12.42	23.64	34.08	12.76	99.60	276	3.9 6.1 8.6 9.6	142 181 172	7.5 10.1 11.7 10.7
211	....	O open....	.....	.12	.04	1.04	24.68	21.94	18.30	11.98	10.24	6.10	5.40	99.84	276	3.8 5.8 7.6 9.6	115 119 118	36.5 44.0 44.5 42.0
238	....	O.........	.....	.04	.02	.12	.62	2.20	7.80	12.40	26.42	32.74	18.24	100.24	336	4.0 6.0 8.0 10.0	...... 171 184 175	4.2 7.2 9.5 7.5
244	....	O open....	.....	.02	.02	.02	2.48	4.02	13.30	18.60	19.54	22.68	19.34	100.02	276	4.4 6.0 8.3 12.1	Too dry 175 163	7.9 10.0 13.4 10.0

The grade numbers are those of the producer. These samples are from different pits located between Mechanicsville and Poughkeepsie.

NEW YORK

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
251	See Footnote	O strong..	.....	.04	.06	.04	.54	1.60	6.34	8.48	19.58	39.62	24.08	100.38	276	4.0 6.0 7.5 9.5 11.8	Too dry 174 188 187	4.0 5.3 6.3 7.2 6.5
259	....	O.........	.....	.04	.08	.12	.50	6.74	29.34	21.44	22.18	15.28	4.46	100.18	144	4.00 6.00 8.00	Too dry 145 138	15.7 18.4 18.4
206	....	Albany No. 1...	.....	.04	.10	.42	3.50	3.04	3.54	4.38	16.08	44.72	18.92	99.74	608	3.7 6.2 8.3 9.7 11.3 13.8 14.8	185 199 199	3.7 6.4 7.1 8.5 9.7 9.7 6.5
228	....	Selkirk No. 1....	.....	.10	.14	.44	6.50	15.06	16.16	14.98	18.86	17.68	9.96	99.88	304	6.0 8.0 10.0	Too dry 140 137	18.3 18.5 15.2
240	....	Albany No. 1 open medium	....		.10	.34	1.02	4.48	11.70	15.82	27.68	26.64	12.26	100.04	244	3.8 5.8 8.0 9.7 11.9	...... 151 153 145	12.2 17.3 15.7 11.4 11.4
241	....	Albany No. 1 open.....	....		.04	.32	1.06	4.16	15.04	21.64	28.64	20.76	7.88	99.54	244	3.0 4.0 5.6 7.9 9.6 11.9 13.2 15.1	Too dry 124 124 133 142 132	21.0 22.0 22.0 18.4 13.8 13.0 13.8 10.7
250	....	Albany No. 1....	.....	.16	.16	.30	4.76	8.08	11.12	10.98	17.10	23.98	24.00	100.64	404	4.4 6.6 8.5 10.0 11.6 13.1 15.4	Too dry 141 176 182 186 202 190	4.0 5.3 5.8 7.2 7.0 10.0 7.5
255	....	Albany No. 1....	.....	.04	.12	.50	2.70	3.08	5.50	12.10	28.68	33.92	13.52	100.16	304	4.0 6.0 8.7 10.4 12.3	147 251 227	4.5 6.5 10.7 13.0 10.7
260	....	1 R. L....	....		.10	.40	1.88	10.24	27.12	19.46	16.16	14.10	10.2	99.72	272	4.3 6.0 8.3 9.9	140 173 149	14.7 21.0 22.7 20.0
362	....	Albany No. 1-P..	.14	.82	.14	1.64	17.16	7.62	5.20	6.90	16.62	28.69	14.68	99.56	....	3.7 6.1 7.5 10.0 13.0	Too dry 196 182	5.1 10.0 10.7 13.8 5.1
364	....	Albany No. 1-E..	.....	.06	.10	1.22	10.22	9.92	11.30	11.10	16.98	23.48	15.78	100.16	576	3.9 5.8 8.0 10.4 12.7	180 206 172	6.7 14.7 14.7 15.7 10.7
366	....	No. 1 S...	.....	3.94	5.22	20.10	14.18	10.54	6.26	4.90	8.22	13.88	12.96	100.20	344	3.0 5.2 7.2 8.9 9.6	Too dry 187 174 152	10.7 21.8 30.0 33.0 30.0
369	....	Albany No. 1-S..	.....	.20	.16	.36	2.36	11.08	20.34	14.64	19.04	22.04	9.70	99.92	240	4.3 6.0 8.0 10.0	Too dry 178 161	...... 14.7 20.0 15.7

The grade numbers are those of the producer. These samples are from different pits located between Mechanicsville and Poughkeepsie.

NEW YORK

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
213	See Footnote	Albany... No. 1½	.....	.46	.64	2.18	11.10	14.96	15.78	13.50	14.84	13.88	12.30	99.64	272	3.8 5.6 8.0 9.6 11.7	161 159 149	2.2 18.4 21.2 25.8 12.2
215	....	Albany No. 1½ medium.	.....	.08	.12	.28	2.48	9.48	22.50	24.50	21.16	13.52	6.46	100.58	272	3.4 5.6 7.9 9.8	Too dry 130 139 126	21.0 24.0 23.0 21.8
239	....	Albany No. 1½ medium.	.....	.....	.06	.16	4.32	16.90	19.18	13.12	15.80	16.02	14.18	99.74	244	4.1 6.1 8.0 9.8	Too dry 159 156	11.8 16.7 19.0 17.3
246	....	Albany No. 1½...	.....	.44	.34	.50	15.04	25.60	16.14	7.52	8.56	11.70	13.88	99.72	304	4.0 5.6 8.0 10.0 11.4 14.0	Too dry 160 161 151	7.5 14.3 ...... 18.2 19.0 11.8
208	....	Albany No. 2....	.....	.22	.52	2.00	29.16	15.64	12.80	8.68	12.14	10.78	7.70	99.64	244	3.6 6.0	148 135 (1)	23.3 29.0
212	....	Albany No. 2 medium.	.04	.18	.36	5.70	28.90	15.86	11.80	8.52	11.16	8.40	9.26	100.18	276	3.4 6.0 8.2 9.5	140 158 145	14.0 27.6 34.0 31.0
245	....	Albany No. 2...	.20	.90	1.16	7.06	37.28	16.82	9.02	4.02	3.80	7.34	12.10	99.70	304	4.7 6.3 8.0 10.0 11.8	Too dry 169 154	13.0 23.4 27.0 44.0 36.0
256	....	Albany No. 2...	.....	.04	.10	1.60	22.24	12.24	8.64	10.20	18.40	15.88	10.88	100.20	304	2.0 4.0 6.0 8.0 10.1	Too 208 174 148	dry 13.8 18.4 21.0 16.7
257	....	Albany No. 2...	.12	.64	.68	8.74	36.24	7.56	5.08	5.60	12.22	12.62	10.60	100.10	304	4.0 6.0 8.0 10.1	138 150 123	13.0 30.0 44.0 18.4
261	....	Albany No. 2-W	.....	.98	2.62	10.08	22.70	18.32	10.56	6.56	8.18	10.34	9.82	100.16	304	3.0 4.0 5.6 7.6 9.9 11.9	117 157 144 127	16.7 23.4 31.0 38.0 44.0 17.8
363	....	Albany No. 2-W	.....	.14	.12	3.88	30.98	11.04	4.76	4.26	9.00	21.74	13.82	99.74	....	3.0 3.9 6.1 7.7 10.0	Too 179 177 167	dry 7.2 14.7 19.0 17.8
365	....	Albany No. 2-E	.....	.20	.18	1.46	17.00	15.42	12.74	9.76	13.78	16.14	13.22	99.90	304	4.2 6.0 8.0 10.3	167 200 168	9.4 16.2 23.4 19.0
370	....	Albany No. 2-NR	.....	.....	.02	1.00	26.50	22.98	11.40	6.10	6.32	9.06	16.70	100.08	....	4.1 6.0 8.3 10.5	Too 241 195	dry 29.0 52.0 31.0
204	....	Albany No. 2½..	.24	.24	.30	3.86	46.44	18.86	7.62	3.50	3.46	6.14	8.72	99.38	272	3.0 5.0 7.0 9.7	Too dry 120 102	35.0 75.0 81.0 67.0
214	....	Albany No. 2½ open....	.14	.16	.10	1.74	35.84	20.50	12.94	6.78	6.78	7.44	6.92	99.84	272	3.0 5.0 8.0 8.6	...... 119 121 110	41.0 68.0 49.5 55.0

The grade numbers are those of the producer. These samples are from different pits located between Mechanicsville and Poughkeepsie.

(1)Appeared wet.

NEW YORK

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
216	See Footnote	Albany No. 2½ medium	.....	.36	.34	2.60	44.70	17.30	9.02	4.54	4.94	6.30	9.92	100.06	272	2.0 3.6 5.8 7.5 9.5	Too 151 141 113	dry 35.0 60.0 70.0 56.0
248	....	Albany No. 2½ medium	.....	.32	.70	3.96	56.74	11.18	5.44	2.74	3.40	6.50	10.06	100.04	244	3.4 5.8 8.0 9.8	Too dry 126 98 91	63.0 112.0 105.0 79.0
262	....	Albany No. 2½-W	.14	.22	.68	6.20	33.64	18.84	10.78	5.34	4.94	7.68	11.38	99.84	276	3.0 4.0 6.0 8.0 10.0	104 158 147 130	15.7 27.0 44.0 52.0 44.0
210	....	Albany No. 3...	.46	.96	1.32	19.14	41.56	5.26	3.08	1.86	2.96	7.60	15.76	99.96	244	4.0 6.0 8.0 10.1	146 173 127	14.0 68.0 169.0 133.0
218	....	Albany No. 3 open....	.78	1.42	2.30	16.50	53.16	3.22	1.50	1.58	2.74	6.34	10.60	100.14	272	3.4 5.8 7.8 9.2	Too dry 132 97	31.0 135.0 190.0 176.0
220	....	Albany No. 3 medium	.64	1.48	2.08	23.20	42.70	4.30	2.00	1.80	3.14	7.10	11.34	99.78	244	4.3 5.7 8.2 9.4	123 (1) 131.5 102	27.3 105.0 143.0 13.8
247	....	Albany No. 3...	.24	2.88	2.94	5.50	52.80	6.72	2.88	1.54	2.58	7.58	14.50	100.16	304	4.0 6.0 8.0 10.0 11.7	Too dry 157 148	9.4 24.2 93.0 96.0 47.0
263	....	Albany No. 3-R	.30	.82	.80	8.00	28.44	19.50	10.94	4.58	4.44	7.88	14.24	99.92	308	2.0 4.0 6.0 7.5 10.0 12.2	Too 161 137 133	dry 19.0 42.0 49.0 49.0 28.0
371	....	Albany No. 3-NR	.....	.....	.02	.72	19.68	20.18	14.50	8.26	9.46	11.40	16.70	100.92	....	4.1 6.0 8.3 10.2	197 247 188	...... 24.2 44.0 34.0
205	....	Albany No. 3½..	.12	.50	.90	.82	52.38	7.64	4.30	2.90	4.98	10.84	15.12	100.50	276	3.0 5.0 7.2 9.4 10.8	149 181 156	7.4 25.0 54.0 80.0 42.0
217	....	Albany No. 3½ medium	.76	2.00	3.30	18.96	32.20	4.34	2.62	3.40	5.62	12.14	14.58	99.92	244	3.9 5.8 8.1 9.5	157 204 167	5.8 16.4 50.0 36.0
219	....	Albany No. 3½ open....	.38	2.24	2.64	5.58	64.08	5.64	2.18	1.50	1.98	4.80	9.18	100.20	244	3.0 4.0 6.0 7.4 9.4	Too 106 103	dry 79.0 185.0 358.0 167.0
252	....	Albany No. 3½..	.60	.74	2.46	1.94	63.00	4.40	1.98	1.30	2.92	8.70	12.74	100.78	244	3.0 5.0 7.0 9.3	Too dry; 158 129 96	12.2 55.0 173.0 162.0
307	....	No. 4.....	.20	.92	1.82	10.02	10.54	6.80	12.90	12.96	13.48	15.40	15.20	100.24	304	2.7 5.0 7.1 9.2 11.5	Too 197 176 163	dry 11.8 19.0 20.0 15.7
368	....	5 R. L....	.....	2.14	3.42	13.60	11.96	7.86	12.20	10.82	12.74	14.50	10.92	100.16	544	2.4 4.8 6.6 8.6	Too dry 154 148 144	6.7 17.8 25.8 24.2

The grade numbers are those of the producer. These samples are from different pits located between Mechanicsville and Poughkeepsie.

(1) Too dry.

NORTH CAROLINA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
1	Selma.........	Molding..	.....	.....	.....	.19	15.20	22.84	11.64	18.35	2.85	.16	28.64	99.87	776	2.8 5.5 7.3 9.6 11.2	106.76 **132.36** 107.75	17.77 33.58 36.09 **39.66** 38.46
2	Selma.........	Cores, Large Castings..	.....	.46	4.08	35.03	27.56	4.14	1.08	1.78	1.44	.58	23.61	99.76	1072	2.9 5.0 7.6 10.0	169.40 **239.30** 189.70	39.0 77.09 **88.42** 63.87
3	Halifax.........	....	.....	20.47	23.03	32.38	6.86	.99	.35	.66	.29	.15	14.75	99.93	1376	5.5 7.5 8.4 9.0 11.8	209.71 **229.80** 211.10	121.70 272.84 356.52 **437.70** 92.30
4	Washington....	Molding..	.....	.....	.12	1.14	14.07	27.71	12.99	20.09	4.69	.68	18.31	99.80	976	2.1 3.8 6.1 7.6	75.59 **141.37** 129.57 111.61	52.66 **53.45** 49.16 ......
5	Washington....	Molding..	.....	.02	.20	1.07	44.60	29.22	9.80	3.79	.14	.05	10.89	99.78	1008	2.2 3.2 5.8 8.0	162.54 **196.10** 132.04 100.50	83.53 **113.90** 94.17 86.89
6	Washington....	....	.....	.....	.10	.92	39.67	22.17	9.65	4.99	.47	.35	21.05	99.27	1408	3.2 5.2 5.8 8.0	176.84 **270.9** 247.0	48.99 61.1 **67.7** 65.0
7	1 Mile W. Pinetown....	Molding..	.....	.06	.71	7.60	64.15	7.54	1.02	.87	.05	.01	17.68	99.69	976	3.2 3.8 5.8 7.9	133.96 **199.10** 174.90 124.00	119.60 **138.86** 128.18 83.67
8	4 Miles N. of Washington..	....	.....	.22	3.04	11.59	39.11	13.65	8.16	6.57	.15	.02	17.21	99.72	976	2.9 4.6 6.8	187.1 **199.9** 163.6	75.48 **102.91** 82.29
9	Wharton Station......	....		.....	2.01	5.94	23.88	12.81	10.41	9.75	.52	8.21	33.80	99.33	1040	4.0 5.3 7.7 10.1	200.4 **233.3** 204.2 162.9	29.1 37.1 **39.37** 38.67
10	Farmville.....	....	.....	.....	.80	3.69	24.28	21.71	15.94	11.17	.26	.54	20.51	98.90	776	2.2 2.8 3.0 6.1 6.9	96.3 **119.2** 111.2 103.4	27.2 33.8 36.83 **44.43** 41.43
11	Pinetops.......	....	.....	.....	.63	1.70	19.43	17.69	12.42	20.54	1.54	1.25	24.60	99.80	904	2.8 5.0 5.8 8.0	132.72 **172.54** 158.95 144.80	...... 25.32 **29.08** 28.15
12	Rocky Mount..	Molding..	.....	.....	.38	1.68	13.12	8.62	6.24	2.80	.04	.....	66.88	99.86	972	5.9 7.7 9.8 11.9	233.32 **246.0** 205.7	5.05 11.65 **12.12** 6.15
13	Goldsboro.....	Molding..	.....	.....	.02	.13	7.10	18.47	16.19	16.46	1.30	1.29	38.58	99.54	1072	3.7 6.2 7.9	172.65 **215.62** 183.71	12.03 **18.00** 16.27
14	Kinston.......	Molding..	.....	.....	.35	1.27	9.45	27.29	29.17	11.92	.50	.41	19.43	99.79	1836	4.0 4.2 6.8 7.6 9.8	222.1 **225.2** 217.73 199.8	44.8 45.19 48.33 **50.12** 32.86
15	Kinston.......	Molding..	.....	.....	.52	1.44	7.71	16.47	25.06	17.93	.82	.89	29.17	100.01	1972	6.6 8.0 9.8	278.69 **285.79** 267.50	37.91 **43.02** 37.91
16	2 Miles N. Granger.....	....	.....	2.59	3.66	5.65	26.55	16.72	16.25	4.20	.26	.93	22.65	99.46	2236	1.8 3.8 5.8 8.0	...... 258.9 **276.2** 266.6	47.96 **71.39** 64.25 53.83

NORTH CAROLINA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
17	Kinston	......	.....	.....	3.06	36.58	30.11	6.00	3.04	1.42	.....	.....	19.81	100.02	1636	2.7 3.8 6.5 8.1	...... 185.62 **363.98** 330.60	132.94 **214.18** 172.23 102.91
18	Kinston	......	.....	1.09	1.41	7.53	47.07	10.91	3.91	2.25	.....	.06	25.55	99.78	1304	2.7 4.8 5.7 10.0	.... 262.17 **299.85** 241.70	51.09 **70.19** 66.12 64.09 ......
19	Newbern	Molding ..	.....	.....	.08	.71	13.70	25.43	4.02	9.77	1.55	1.30	43.50	100.06	1308	4.0 5.4 7.3 9.8	...... 241.0 **267.9** 260.0	9.29 **28.18** 27.72 ......
20	Wilmington	Molding ..	.....	.....	.63	2.71	15.49	15.36	9.96	11.23	.11	.36	44.06	99.91	576	3.0 4.9 6.0 8.2	...... 231.51 **250.80** 220.30	8.47 **21.77** 20.75 19.84
21	Leland	......	.....	.....	3.56	15.72	31.21	8.21	4.19	3.33	.03	.47	33.16	99.88	1172	2.7 6.0 7.2 9.2	91.71 256.6 **307.4** 296.9	42.82 52.30 **78.31** 53.20
22	Town Creek ...	......	.....	.....	.03	.93	11.45	24.24	19.48	14.55	.23	.92	28.15	99.98	936	2.6 4.8 7.1	139.75 **242.65** 212.24	35.39 **62.17** 43.10
23	Wilmington	......	.....	.....	.96	15.79	53.72	9.29	.92	2.42	.01	8.02	16.51	99.64	808	6.1 7.0 8.7 9.8	160.6 **216.3** 186.9 146.8	139.0 **227.8** 116.6 94.4
24	Fayetteville ...	Molding ..	.....	1.02	4.84	15.10	38.78	8.57	2.29	1.41	.01	.....	28.00	100.02	1104	5.7 7.5 11.5 12.4	177.85 274.76 **307.50** 288.40	62.96 **99.44** 84.51 ......
25	3 Miles S. W. Fayetteville.	Molding ..	.....	.45	1.45	5.24	26.49	27.22	12.56	4.29	.03	.06	22.20	99.99	576	3.4 4.7 5.8 7.2 9.3	134.3 226.5 **305.9** 245.3 205.9	29.3 41.8 74.8 **99.24** 45.7
26	2 Miles W. Gibson	......	.....	3.08	6.09	11.69	21.14	7.80	4.16	9.16	.18	.30	36.30	99.91	672	5.7 7.9 9.7	256.6 **301.2** 254.9	24.5 **66.07** 36.45
27	Lillington	......	.....	.....	.09	.47	11.92	13.69	10.99	17.37	.40	.31	44.74	99.98	1072	9.8 10.8 12.3	285.8 **292.6** 253.7	47.0 **60.4** 50.62
28	Mt. Holly	......	.....	.....	.25	2.23	19.23	12.90	9.52	11.10	.44	.64	43.69	100.00	640	5.7 7.5 10.6 12.8	162.6 **177.4** 161.8	8.72 12.16 13.24 **15.64**
29	Mt. Holly	......	.....	.....	.12	1.95	22.63	13.58	7.24	11.65	.04	.43	42.43	100.07	776	5.2 7.1 9.5 12.6	166.57 205.7 **217.0** 195.6	6.02 12.59 **20.71** 16.23
30	Mt. Holly	Molding ..	.....	.....	.63	8.37	22.90	8.54	5.75	4.33	.06	.08	49.31	99.96	904	5.7 7.9 10.0 13.0	253.00 **283.20** 277.60	...... 22.60 **23.68** 19.77
31	Hickory	Molding ..	.....	1.27	2.92	10.19	24.39	9.33	4.80	7.77	.01	.61	38.66	99.95	576	5.3 6.8 7.8 10.0	145.83 **197.80** 186.40	...... 15.17 26.71 **45.85** Too wet
32	3 Miles W. Hickory	Molding ..	.....	.73	5.45	15.45	23.28	8.98	5.72	9.45	.49	1.80	28.33	99.68	476	3.0 3.5 5.9 7.8 10.0	148.70 **176.50** 163.26 148.62	.... 42.18 **50.42** 23.86

NORTH CAROLINA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
33	1 Mile E. Hickory.....	Molding..	.....	.84	1.79	9.89	19.98	8.36	.63	14.01	.06	.69	43.65	99.90	776	6.0 8.0 10.2	205.40 253.39 242.00	29.91 33.66 65.81 Too wet
34	3 Miles W. Hickory.....	Molding..	.....	.57	1.75	2.29	6.85	8.72	10.04	23.16	.24	1.29	45.04	99.95	608	6.0 8.4 9.9 12.0	156.97 182.80 163.70	13.91 16.01 17.04 15.52
35	Catawba......	....	.....	.....	.11	.44	3.04	3.49	4.06	13.69	.63	1.46	73.06	99.98	936	8.5 10.6 12.6 13.7	185.95 212.00 224.56 209.30	3.73 4.01 3.65 ......
36	Statesville.....	....	.....	.....	.....	.52	13.57	15.32	13.18	20.10	.89	4.02	32.28	99.88	576	5.9 8.0 11.3 13.0	131.3 154.3 166.5 137.0	7.57 10.48 12.04 12.53
37	1 Mile E. Statesville...	Molding..	.....	1.17	1.88	5.29	16.03	8.03	5.80	12.79	.86	2.80	45.21	99.86	576	6.1 7.9 9.8 12.0	201.05 214.70 208.40	...... 7.32 10.81 12.24
38	Statesville.....	....	.....	.36	.66	2.13	7.25	5.47	4.84	15.64	.34	7.41	55.88	99.98	544	8.9 10.0 12.2	205.90 207.60 165.92	8.27 9.22 14.79
39	Statesville.....	Molding..	.....	.39	1.49	5.79	24.75	13.22	3.47	15.89	.09	.60	34.24	99.93	572	4.4 6.4 8.1 10.0 12.0	138.73 215.50 202.90	...... 25.84 33.34 33.61 25.97
45a	....	....	.....	.....	.01	1.00	77.76	18.52	2.49	.21	.02	.01	.....	100.02	.....	.....	......	......
46a	....	....	.....	.....	.25	8.55	70.56	15.37	3.33	.93	.49	.79	.....	100.27	.....	.....	......	......
319	....	Molding..	.....	.88	4.70	28.94	31.48	4.68	2.34	1.30	1.50	3.30	21.30	100.42	776	3.2 4.0 6.6 8.7 10.7	169.00 285.00 223.00 161.00	235.00 ...... 278.00 278.00 30.00

PENNSYLVANIA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strenght	Permeability
601	Burnham Mifflin Co...	Steel.....	.....	.11	.31	4.51	64.26	21.33	5.56	1.69	1.15	1.00	.....	99.92	....	0	......	118.
602	Montoursville Lycoming Co.	Cores and Plaster...	.....	.22	.12	1.57	38.34	36.12	10.86	3.41	3.38	5.75	.....	99.77	....	0	......	24.7
603	Hamburg Burks Co....	Heavy Iron Castings.	.....	.04	.70	5.58	14.32	12.98	10.12	5.88	7.80	13.92	28.90	100.24	....	5.8 6.4 8.5 10.4 12.3	219 294 288 253	...... 4.7 10.7 27.0 10.7
604	Hamburg Burks Co....	Heavy Iron Castings.	.....	.20	.22	5.48	34.48	15.40	8.98	4.78	5.74	8.28	16.44	100.00	....	4.3 6.2 8.3 9.9	175 201 182	15.7 36.0 62.0 44.0
605	Berne Burks Co.........	Uses Unknown..	.....	.20	.26	2.00	5.66	6.70	8.02	6.16	9.88	18.52	42.50	100.00	....	6.8 8.7 10.8 12.0	261 277 311 (Too wet)	3.1 7.7 13.8 ......
606	Slatedale Lehigh Co..	....	.....	.....	.....	.04	4.10	14.96	17.10	13.44	17.30	22.74	10.16	99.84	....	3.9 5.8 8.1 10.3 12.5	(1) 132 133 146 143	9.0 13.8 17.8 20.0 21.8(2)
607	Allentown, S.E.	Cores.....	.....	7.04	11.10	24.38	20.40	6.60	3.34	1.76	2.48	5.90	17.32	100.22	....	5.9 8.2 10.1 12.1	160 163 182 150	6.7 17.3 33.0 12.0(3)
608	Allentown Pit W. of Emans.	Castings 100 lbs.	.....	.04	.08	.22	2.00	7.40	10.36	9.42	16.92	26.40	27.28	100.12	....	6.1 8.0 10.2 12.5	(1) 165 150	7.2 10.0 12.2 11.4
609	Ridgway......	....	.....	1.04	3.90	22.86	30.78	7.10	3.36	1.78	2.04	6.04	20.94	99.84	....	4.2 6.2 8.1 10.2 11.8	151 197 197 170	19. 34. 67. 67. 49.
610	Ridgway......	....	.....	.....	.04	5.50	40.04	11.48	6.04	3.32	4.02	8.52	20.82	99.78	....	6.1 8.3 10.2 12.3	217 227 191	11.8 28.0 36.0 19.8
611	Catawissa.....	Medium	.....	.26	.46	2.00	13.24	6.20	4.94	5.70	16.14	38.82	12.18	99.94	344	3.9 6.1 8.1 10.3 12.4	...... 131 157 157 159	7.7 12.2 11.4 10.7 (3)
612	Catawissa.....	Fine grade...	.....	.38	.84	4.62	4.74	4.66	6.44	8.56	21.54	37.10	10.80	99.68	344	4.2 6.0 8.2 9.7 12.3	155 174 173	6.7 7.7 8.2 9.7 9.4
613	Tullytown.....	No. 0.....	.....	.16	.26	3.26	12.66	6.36	5.46	6.22	12.64	25.48	27.46	99.96	704	6.4 8.5 10.4 12.7	203 209 194	7.9 9.4 12.2 6.7
614	Tullytown.....	No. 4.....	.....	.10	.50	5.60	24.54	11.60	7.32	4.84	7.44	17.16	20.44	99.54	376	6.1 8.4 10.4	185 199 162	15.7 22.7 14.9
615	Winfield.......	No. 1.....	.....	.....	2.80	27.45	53.65	8.53	3.37	1.23	.98	1.73	.....	99.74	72	0	......	155.
616	Winfield.......	No. 2.....	.....		.04	9.52	67.49	13.12	9.80	1.49	1.25	1.79	.....	99.50	40	0	......	112.
617	Winfield.......	No. 3.....	.....		.40	3.62	17.05	28.80	22.32	11.96	8.50	7.07	.....	99.72	144	0	......	22.
618	Emlenton......	....	.....	.05	.70	4.60	57.88	26.46	6.81	1.57	.69	1.11	.....	99.87	72	0	......	100.
619	Emlenton......	....	.....	.06	1.03	7.17	66.44	19.29	4.34	.80	.49	.29	.....	99.91	72	0	......	143.
343	Danville.......	No. 6.....	.....	.12	.02	.12	1.86	6.76	10.50	11.06	22.40	35.04	12.62	100.50	544	4.0 6.0 7.0 8.8 14.7	(1) 150 145	7.9 10.1 11.0 17.8 8.8

(1) Too dry. (2) Getting too wet. (3) Too wet

TENNESSEE

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 21	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
C-1	Fish Springs	......	.....	1.81	3.82	8.10	22.64	8.52	5.18	11.70	.39	6.98	30.85	99.99	1404	5.9 7.3 9.4 11.1	167.66 194.32 199.20 176.90	9.22 13.08 31.29 27.23
C-2	Braemar	Molding Sand	......	......	.57	3.64	42.67	11.61	1.85	7.24	......	.05	32.32	99.95	576	5.9 7.8 9.7 12.7	110.29 143.40 123.50	36.62 46.86 73.19 53.29
C-3	Wautauga Station		......	.22	.24	3.28	20.70	11.62	6.82	4.80	5.42	9.90	36.70	99.70	1304	6.5 8.5 10.3 11.4 12.3 13.0 14.8	Too dry 261.00 273.00 285.00 305.00 338.00 333.00	10.30 17.30 18.40 24.20 42.00 38.00 34.00
C-4	½ Mile E. Mt. Olivet Station	....	.26	.48	.70	.54	26.14	15.48	5.68	2.98	2.98	6.52	37.86	99.62	1336	6.8 9.2 11.0 13.1 15.0	232.00 300.00 343.00 390.00	31.00 47.00 55.00 55.00 6.50(1)
C-5	St. Elmo	Molding Sand	.....	4.94	2.47	4.53	21.86	5.26	2.89	3.52	......	.11	54.42	100.00	704	5.8 8.0 10.2 13.1	154.18 225.02 328.60 308.10	80.01 106.09 89.45 ......
1	1 Mile W., Roger's Springs Station	....	......	......	.26	6.80	26.72	13.38	16.12	8.28	1.64	3.96	22.36	99.52	704	4.0 6.0 7.2 7.9	161.90 285.90 279.90	47.0 27.53 55.20 25.54
2	1 Mile W. Roger's Springs Station	....	......	......	4.90	18.80	35.52	10.28	6.28	4.68	.94	4.18	16.72	99.30	1008	4.0 6.0 7.8	236.50 260.10 206.10	62.65 70.30 44.00
3	Saulsbury	....	......	......	1.18	18.56	50.26	14.92	6.50	2.94	.62	.96	3.73	99.67	344	Dry	......	142.75
4	Saulsbury	....	......	......	3.24	17.04	21.72	5.84	2.32	1.30	.38	11.76	36.01	99.61	1872	3.9 6.1 7.9 10.0	...... 344.79 361.53 325.80	11.30 31.16 13.39 ......
5	1 Mile S. Grand Junction	....	......	4.51	5.77	14.75	14.00	2.78	1.56	1.37	.94	14.28	40.35	99.95	2436	3.8 6.5 7.9 8.6	131.00 347.80 343.00 318.00	4.01 49.40 30.09 ......
6	1 Mile S. Grand Junction	....	......	5.38	10.74	42.56	29.88	1.98	.64	.48	.38	.32	7.80	100.16	872	4.8 6.0 7.8 10.5	...... 90.55 107.66 78.80	251.60 275.14 172.81 ......
7	La Grange	....	......	1.92	4.94	26.90	43.40	7.20	2.68	1.30	.50	.28	11.89	101.01	1436	2.9 4.0 7.9	236.20 322.80 237.60	175.40 220.00 128.40
8	La Grange	....	......	.24	3.20	15.40	39.34	14.40	3.12	2.72	.18	.04	21.34	99.98	1436	2.8 4.0 5.8 7.9	146.40 334.90 331.30	...... 61.29 100.95 71.55
9	La Grange	....	......	2.64	6.16	41.62	39.74	3.74	1.08	.42	.30	.24	4.05	99.99	308	Dry	......	322.93
10	2½ Miles S. W. Bolivar	....	......	.90	1.88	24.58	39.06	7.78	3.34	1.68	1.02	.14	19.48	99.86	1336	3.7 6.3 8.2 9.4	187.80 246.90 151.20	...... 114.90 122.71 116.04
11	2½ Miles S. E. Bolivar	....	......	.04	.24	2.68	5.78	1.42	.80	.68	.72	7.64	80.11	100.11	2704	5.0 7.1 8.0 9.8	231.0 238.7 224.9	1.0 4.8 5.58 3.17
12	1½ Miles S. E. Saulsbury	....	......	.22	.94	8.18	15.60	5.72	3.54	3.34	2.12	4.42	55.71	99.79	2104	4.2 7.1 8.0 9.0 11.0 12.8	172.9 336.3 250.5 214.9 187.4	...... 8.09 9.5 15.7 25.6 23.6

(1)Very wet.

TENNESSEE

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
13	1½ Miles S. E. Saulsbury....	....	.....	.38	.94	12.52	46.44	16.62	6.60	.22	4.44	.58	10.89	99.63	576	3.8 5.4 6.9 9.1	124.3 101.4 92.8	...... 111.2 116.5 68.46
14	Rossville......	....	.....	.56	2.40	19.84	42.48	10.24	6.60	.34	.72	.98	14.56	99.72	1136	2.9 3.8 6.0 8.0	244.8 329.1 232.6 141.0	116.55 204.30 99.21 94.61
15	1½ Miles E. Rossville....	....	.....	.68	3.46	21.00	41.50	11.18	4.28	.16	2.72	.60	14.00	99.58	1372	2.0 3.0 4.2 5.5	...... 266.4 306.9 226.0	69.61 133.00 131.88 102.00
16	Moscow......	....	.....	.....	1.64	26.76	50.08	8.96	1.46	1.24	.10	.10	9.52	99.86	472	1.0 2.0 3.7 5.5	Too dry 117.5 89.2 72.0	251.85 290.30 287.00 284.70
17	Moscow.......	Molding Sand...	.....	.12	.78	10.12	51.92	13.88	4.74	.26	2.38	3.40	12.17	99.77	1072	2.1 3.8 5.7 8.1	184.7 213.1 155.1 122.2	...... 102.28 116.80 85.30
18	Saulsbury.....	....	.....	.46	4.42	22.58	38.62	9.76	4.60	1.96	2.50	2.04	12.88	99.82	1472	2.5 3.6 6.3 8.0	174.16 308.70 261.2 172.4	92.6 140.37 64.9 47.5
19	Selmar Station	....	.....	.02	.24	10.60	45.26	6.40	2.14	.04	2.24	5.48	27.08	99.50	1904	6.3 7.8 9.5	208.4 309.1 270.8	63.28 70.0 40.6
20	1½ Miles S. Henderson...	....	.....	.....	.04	4.52	48.22	10.38	3.01	.44	1.36	8.64	22.56	99.17	1904	4.0 5.2 7.0 7.6	262.9 274.1 244.1	21.93 49.28 68.00 49.77
21	1½ Miles S. Henderson...	....	.....	.....	.04	7.32	67.68	10.28	2.04	.00	.80	.30	11.17	99.69	240	4.0 5.3 6.6 10.0	...... 70.52 79.10 76.33	283.9 350.4 298.3 ......
22	4 Miles E. Jackson.....	....	.....	.68	1.96	15.88	43.54	11.58	5.44	.80	8.26	.90	14.71	98.75	1536	1.7 2.9 4.0 7.9	...... 160.56 273.90 189.80	59.73 107.00 92.9 89.6
23	4 Miles E. Jackson.....	....	.....	1.94	4.68	26.26	53.28	7.54	1.76	.26	.24	.18	3.47	99.61	376	Dry	......	213.09
24	1 Mile N. Jackson.....	....	.....	.14	.14	1.52	27.92	7.44	1.02	1.08	5.18	24.66	29.78	98.90	1408	6.0 7.7 9.4 11.8	226.9 242.9 218.0	8.6 20.9 23.1 5.66
25	4 Miles N. Jackson.....	....	.....	.28	.78	20.68	28.52	6.84	1.98	.32	3.44	9.04	29.32	101.20	1904	3.9 6.1 8.0 10.4	160.95 285.90 271.50	...... 34.20 37.51 20.25
26	4 Miles N. Jackson.....	....	.....	.24	2.56	52.38	26.70	2.50	.70	.82	.34	1.04	12.50	99.78	1040	Dry 2.5 3.7 5.9	...... 176.41 253.78 129.22	272.3 439.6 376.8 331.9
27	4½ Miles N. Jackson.....	....	.....	.94	1.10	7.04	37.78	14.74	.10	.10	10.72	4.94	21.37	98.83	1376	2.4 4.2 5.1 7.5	...... 203.00 280.71 272.81	37.16 84.89 78.60 45.60
28	3 Miles N. Jackson.....	....	.....	.12	.28	5.16	63.96	9.30	.90	3.40	.08	.52	15.46	99.18	976	3.6 5.9 7.7 9.0	202.04 255.99 193.50	111.90 119.20 124.98 65.42
29	½ Mile N. Medon Station......	....	.....	.18	.94	14.44	40.38	9.72	4.02	5.84	.46	4.64	17.42	99.44	1636	3.1 4.3 5.9 6.3 7.8	231.50 263.03 246.90 225.68	...... 46.04 98.20 60.24 59.73

TENNESSEE

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
30	½ Mile N. E. Jackson	....	....	.38	1.88	15.32	37.34	7.34	2.18	2.38	.16	4.84	27.91	99.73	2136	5.4 7.2 8.9	253.6 **270.3** 238.2	71.79 **80.50** 61.67
31	2 Miles N. E. Lexington Court House	....	....	....	.46	13.38	25.52	6.57	2.13	1.78	.07	10.00	39.23	99.14	2204	7.6 9.8 11.1 12.4	...... 294.7 **340.0** 337.6	19.30 **22.62** 9.92 1.76
32	Hollow Rock Junction	....	....	.53	1.87	12.55	16.87	5.20	2.03	2.54	.45	14.13	42.81	98.98	2736	7.6 8.9 10.9 13.2	...... 324.6 **347.7** 345.0	27.78 **69.61** 46.20 ......
33	½ Mile S. W. Sawyer's Mills Station	....	....	....	.07	.17	1.32	11.80	40.08	35.65	.44	.56	9.76	99.85	508	1.9 3.7 5.4 7.0	...... 151.99 **180.87** 120.30	37.50 **54.30** 48.30 46.80
34	½ Mile S. Sawyer's Mills Station	....	....	....	....	.10	.73	9.01	39.17	36.27	.55	2.13	11.56	99.52	840	2.1 3.9 5.5 7.6	...... 130.8 **139.8** 122.8	27.4 **36.3** 34.1 17.06
35	1½ Miles W. Huntingdon Court House	....	....	....	.04	3.10	36.91	11.44	3.48	1.54	.18	14.63	27.82	99.14	1436	3.9 5.7 7.8 9.8 11.4	203.1 **216.7** 204.2 188.2	6.2 8.65 13.4 **16.8** 13.99
36	2½ Miles N. W. Huntingdon Court House	....	....	.62	2.45	16.73	39.62	9.48	3.16	1.71	.28	1.69	24.05	99.79	2004	6.1 7.7 9.7	319.9 **340.2** 306.8	141.2 **148.28** 61.9
37	Sawyer's Mills Station	....	....	.29	.05	.20	1.87	15.78	47.68	26.72	.53	.44	6.23	99.79	344	2.0 3.2 4.0 5.3 8.1	...... 96.9 **98.32** 96.67	56.50 64.00 **64.50** 61.10 45.53
38	Sawyer's Mills Station	....	....	.08	.06	.21	2.38	11.18	38.07	23.08	.64	.43	23.54	99.67	1304	4.1 7.1 12.0	123.7 **296.6** 251.0	23.20 **45.51** 12.10
39	Sawyer's Mills Station	....	....	....	.26	11.17	56.32	21.36	3.82	1.31	.79	.41	2.78	98.22	408	2.6 3.3 4.2 5.9 7.6	77.9 **90.1** 84.7	.... 190.2 **331.9** 293.7
40	1 Mile E. Sawyer's Mills Station	....	....	.18	.03	.23	1.12	5.36	35.83	45.59	1.27	.63	9.63	99.87	408	3.0 4.5 5.9 8.0 10.2	127.9 **134.1** 121.6 119.3	...... 38.2 **39.5** 39.3 29.2
41	Lipe	....	....	.31	.01	.08	.56	2.36	24.40	58.65	.91	1.23	11.08	99.59	608	5.5 8.0 9.9	115.11 **137.8** 131.3	19.41 **22.60** 20.88
42	1 Mile E. Sawyer's Mill Station	....	....	....	.05	.10	.33	2.06	27.87	51.04	.37	.34	17.74	99.90	576	4.1 6.0 8.2	165.4 **204.7** 196.5	20.3 **25.98** 23.16
43	Springville	....	....	....	.05	.69	6.06	12.90	23.12	18.62	.54	3.49	32.32	97.79	1336	4.5 6.0 8.0 9.2	232.9 **292.2** 228.8	...... 16.03 **27.46** 23.02
44	1 Mile N. Whitlock	....	....	....	1.10	12.41	36.76	7.36	2.82	3.07	.37	3.27	31.79	98.95	1376	3.0 5.2 6.3 7.4	138.5 **245.0** 224.8	18.5 24.8 **47.7** 21.9
45	2 Miles N. McKenzie	....	....	.16	.41	3.75	36.18	10.78	3.54	3.69	.38	7.73	32.48	99.10	1736	4.4 5.9 8.9	148.7 **267.9** 258.6	35.7 **46.3** 33.8
46	6 Miles E. Tiptonville	....	....	....	.10	.60	.91	.27	.21	1.08	.74	51.31	43.10	98.32	1496	3.7 6.3 8.3 9.8	166.4 **207.0** 191.2	1.4 1.79 **2.40** 1.76

TENNESSEE

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
47	Dyersburg.....	....	.....	.....	.....	.07	.13	.06	.07	.19	.07	.39	99.00	99.98	2672	3.8 5.8 7.8 9.8 13.0	151.7 210.2 181.4 130.9	...... 1.48 1.9 2.04 2.03
48	Dyersburg.....	....	.....	.....	.10	.13	.08	.06	.06	.47	.25	.80	98.00	99.95	4604	5.5 7.7 9.1 11.5 12.0 12.9	208.2 283.6 254.0 246.4 229.7	1.0 1.0 2.3 3.3 3.8 3.2
50	1.2 Miles S.W. Whiteville...	....	.....	2.07	1.20	8.98	23.86	2.05	.98	1.52	.06	.44	58.72	99.88	2772	6.4 8.6 9.5 10.2 11.5	236.8 302.6 297.7 225.6	24.9 27.8 51.1 70.79 58.27
51	3 Miles W. Somerville...	....	.....	.....	.12	2.43	27.43	7.29	2.33	.77	.....	.04	59.46	99.87	2304	4.7 6.5 8.5	178.1 273.5 270.5	9.7 15.4 12.5
52	¼ Miles S. Cox Bridge......	....	.....	.....	.03	.07	11.25	13.69	12.36	12.52	.48	.32	49.12	99.84	1040	4.5 6.2 8.1 9.8 12.0	173.7 213.6 207.4 188.5	7.9 14.5 19.6 25.8 15.6
53	¼ Miles S. Cox Bridge..	....	.....	.....	.17	.89	8.69	3.35	2.75	7.48	.06	.07	76.48	99.94	2336	8.6 11.8 12.1 13.0 14.0	212.4 301.5 275.5	.... 5.0 7.41 mud
54	Ripley........	....	.....	.....	.....	.20	.43	.14	.08	.08	.....	.18	98.83	99.94	2776	6.3 8.3 10.0 11.6	209.3 232.9 230.7	1.32 1.66 2.07 2.04
55	Memphis......	....	.....	.05	.07	.26	.34	.12	.13	.51	.19	3.64	94.38	99.69	4408	7.8 9.4 10.0 11.6	199.65 243.1 239.8	2.94 2.04 6.01 4.29
56	Memphis......	....	.....	.....	.....	.10	.27	.14	.11	.39	.14	2.06	96.61	99.81	2808	4.0 6.3 7.6 10.1 12.0 12.7	168.3 213.8 210.4	...... 1.03 1.97 2.09 2.11 2.03
57	Hollywood....	....	.....	3.31	24.15	44.14	26.69	1.03	.21	.....	.....	.....	.49	100.02	8	Dry	......	438.89
58	Memphis......	....	.....	.....	.20	.62	2.25	1.57	1.71	3.56	.19	.03	89.82	99.95	3472	4.0 6.1 7.8 9.4 11.5	...... 196.5 204.3 234.4 242.4 Mud	1.08 .50 1.27 ....
59	Memphis......	....	.....	.....	.70	.65	.63	.22	.22	.60	.08	1.29	95.28	99.67	3736	7.7 9.5 11.1 11.9 Mud	211.3 229.9 248.5	1.50 3.00 6.39 4.36 ......
60	Pittsburgh Landing.....	....	.....	.....	.....	.10	10.71	12.16	11.82	19.01	1.54	1.26	43.03	99.63	1136	6.1 8.1 9.6 10.6	...... 194.21 236.07 214.30	10.74 24.30 22.52 ......
61	Swallow Bluff Landing.....	....	.....	.21	.22	.93	3.78	1.79	1.48	1.02	.....	.01	90.60	100.04	3340	3.8 6.4 8.2 11.4	...... 108.17 148.56 289.46 (Too wet)	1.12 58.89 8.50 8.50
62	3 Miles N. Savannah...	....	.....	.34	.87	1.66	2.57	2.89	1.50	1.28	2.77	1.24	84.66	99.78	2536	7.3 8.7 10.1 11.9	...... 240.66 267.15 234-65	1.95 9.10 7.16 3.76

TENNESSEE

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
63	Parsons.......	....	.....	1.62	1.17	3.77	14.32	8.15	2.26	2.98	.24	.23	64.99	99.73	2604	6.0 7.5 9.0 13.9	...... 209.09 247.79 **386.75** Too Wet	13.00 **18.94** 16.70 ......
64	½ Mile S. Perryville...	....	.....	.08	.04	.23	6.45	10.15	7.71	1.52	.01	.....	73.79	99.98	1604	6.2 7.9 9.8 11.9 12.4	190.96 **223.02** 222.64	2.36 6.47 9.28 **13.25** 10.71
65	1½ Miles E. Darden......	....	.....	.08	.39	.78	3.52	8.86	5.88	12.15	3.60	.25	64.40	99.91	1836	7.7 9.8 11.8 13.1	213.42 **228.20** 217.30	...... 6.18 **7.24** 5.15
66	3 Miles S. E. Lexington....	....	.....	.....	.09	.27	2.78	3.88	20.89	21.27	.34	.11	50.30	99.93	2708	8.6 9.5 12.0 13.4	...... 294.45 **308.30** 284.10	8.10 **12.69** 11.12 ......
68	3 Miles S. E. Lexington....	....	.....	.....	.....	.14	5.02	9.16	30.03	30.89	.33	.04	24.12	99.73	544	5.8 7.8 9.5	109.84 **116.48** 115.00	23.10 **26.63** 22.16
69	2 Miles S. E. Lexington....	....	.....	.....	.07	.62	3.56	10.11	19.23	44.86	1.64	.07	19.36	99.52	344	3.4 5.6 7.7 9.7	...... 94.47 **99.41** 97.36	39.30 **45.19** 43.43 35.19

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
1	Petersburg....	Brass.....	.....	.20	.10	.48	5.34	28.48	8.24	31.48	3.24	4.20	18.20	99.96	1536	4.3 5.0 7.0 8.0 9.0	**314.** 296. 272.	23.4 24.8 **28.5** 28.3 ......
2	Petersburg....	Brass Iron Castings.	.....	.34	.30	.50	3.00	17.14	6.90	34.90	6.70	9.90	20.10	99.78	1936	4.0 5.0 5.7 7.6 8.4	...... **318.** 318. 302.	**21.** 20. ...... 20.4 16.5
3	Petersburg	Dixie Core Sand....	4.34	15.84	21.54	27.00	8.80	2.34	.78	2.00	.58	2.30	14.48	100.00	408	4.0 5.6 7.0	108 (1) **133.** 92 (2)	....
4	1 Mile E. Petersburg...	....	8.30	26.98	14.30	21.24	21.00	3.00	.68	1.24	.24	.84	2.96	100.78	176	0	......	......
5	Petersburg....	....	5.18	10.28	12.38	40.20	20.50	2.64	12.90	1.30	.14	.68	5.00	111.20	376	0	......	550.
7	Petersburg....	....	15.22	20.10	15.09	30.50	14.62	2.32	.59	.82	.09	.22	.....	99.57	104	0	......	710.
8	Hopewell......	....	1.18	8.58	16.28	37.94	21.40	2.60	.54	1.00	.14	.56	10.10	100.32	472	2.0 4.2 6.2 8.1	92. **90.** 64. 57.	650. **1060.** 780. 650.
11	Petersburg....	....	14.67	24.49	16.89	20.76	18.60	2.95	.32	.47	.30	.30	.....	99.94	144	0	......	287.
12	1 Mile W. Petersburg...	Molding Sand...	.....	1.80	4.94	15.38	26.58	14.04	4.68	10.64	1.04	5.58	15.32	99.94	904	3.4 4.3 5.0 6.0 6.3 8.0 8.5	182. 225. 255. **275.** 267. 223.	...... 43.6 60.0 86.4 **111.0** 90.0 86.4
13	Petersburg....	....	2.42	14.12	22.50	43.00	15.85	1.15	Tr.	.15	.60	.15	.....	99.94	44	0	......	1350.
15	Port Walthall Sta.	....	2.39	11.65	16.60	40.30	20.47	4.10	.65	1.50	Tr.	.92	.....	98.78	44	0	......	287.
16	1 Mile N. Carson......	....	.....	1.58	3.80	15.70	20.04	8.20	2.64	8.98	1.88	8.80	28.38	100.00	576	4.0 5.0 6.5 8.0 9.0	...... 185. **205.** 196.	5.6 9. 13.9 **41.7** 12.5
18	½ Mile N. Huska Sta...	....	.....	20.05	20.09	25.52	23.52	4.30	.30	4.42	.25	.65	.....	99.10	176	0	......	1200.
19	7 Miles N. E. Petersburg...	....	4.42	13.75	17.50	30.50	21.80	6.60	Tr.	3.15	1.57	.95	.....	100.24	72	0	......	358.
22	Petersburg....	....	.....	1.99	7.47	36.70	35.47	9.35	2.47	4.09	.50	1.10	.....	99.14	8	0	......	376.
24	Chester.......	Molding Sand...	.....	.....	.28	3.38	25.18	23.00	7.30	19.80	2.14	1.98	16.28	99.34	976	4.2 6.4 7.5 9.4	**349.** 220.	**94.8** 51.6 42.1 31.6
25	Richmond.....	Iron Castings.	.....	1.50	5.60	12.04	4.94	5.14	3.34	36.58	4.98	7.74	17.00	98.86	2504	4.0 6.0 7.4 9.0 9.4 10.0	...... 276. 275. 277. **278.** 251.	16.2 17.0 **17.2** 17.0 15.8 13.2
26	Richmond.....	....	.....	.18	1.08	2.50	3.04	12.64	12.04	48.54	4.94	7.90	6.80	99.66	2336	5.0 7.0 8.0 9.4 10.7	236. 240. 241. **254.** 210.	.... 21.1
27	Highland Park Richmond...	Molding Sand...	.....	.....	.20	.34	3.28	25.78	18.08	26.04	3.14	6.30	16.50	99.66	936	4.0 5.5 7.0	**278.** 256. 224.	42.8 **43.6** 41.4
28	Highland Park, Richmond...	Molding Sand...	.....	.10	.36	.54	1.94	25.44	19.24	26.74	6.24	5.10	10.10	95.80	1104	4.0 4.6 6.3 7.2 9.0	**196.** 186. 159.	33.0 36.1 40.1 **42.0** 39.8

(1) Too dry. (2) Feels wet.

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
29	Richmond.....	Molding Sand...	.....	.84	1.34	2.58	2.98	10.88	8.58	45.70	3.30	6.90	16.90	100.00	2536	5.3 7.0 9.0	**241.** 226. 221.	**26.9** 25.9 ......
30	Varina Grove..	....	.....	.08	.44	8.04	52.54	6.10	1.00	2.04	.34	2.30	27.02	99.90	1104	5.4 7.0 7.8 9.5 10.4	...... 261. 314. **400.** 314.	63.2 83.5 93.1 **124.2** 89.6
31	1 Mile S. W. Dutch Gap..	Core Sand	3.14	13.88	17.88	30.58	10.34	2.68	.90	1.94	.34	.96	16.90	99.54	1136	3.6 4.8 6.4 9.0	...... 201. **212.** 198.	61.4 301. **354.** 210.
32	Richmond.....	....	6.60	7.87	6.40	24.59	50.97	1.65	1.55	.15	.....	.24	.....	100.02	40	0	......	219.
34	Richmond.....	....	.....	1.05	.85	11.49	72.60	10.77	1.24	1.50	.14	.14	.....	99.78	72	.....	......	......
35	Richmond.....	Iron Molding	.15	.38	.78	1.44	1.94	11.80	7.58	47.40	4.24	5.54	18.66	99.91	....	4.0 5.5 6.5 8.0	...... 221. **235.** 220.	26.8 **27.9** 26.3 24.3
36	Between Chester and Centralia....	....	.....	Tr.	1.34	6.72	16.58	18.18	7.78	19.20	2.40	5.80	22.00	100.00	....	4.0 5.2 5.6 7.2 8.5	173.(1) **267.** 236. 236. 209.	31.1 44.8 49.8 **58.0** 29.3
37	Between Chester and Centralia....	....	.....	.14	.64	6.44	18.18	21.04	7.48	17.10	1.94	7.04	19.52	99.52	....	4.0 5.6 8.0	**135.** 135. 103.	24.2 44.7 **47.3**
38	Between Chester and Centralia....	....	.....	3.80	1.16	6.80	14.54	15.48	6.58	19.54	2.24	5.88	24.00	100.02	....	5.7 7.0 7.7 10.0 12.0	211.(2) 273. 277. 285. **295.**(3)	26.9 **43.3** 37.4 32.4 21.0
39	Just E. of Falmouth...	....	1.24	.88	.78	1.50	2.50	5.30	4.58	44.10	4.38	6.54	28.06	99.86	....	5.3 6.7 8.2 9.2	197. 323. **355.** 335.	15.0 16.0 **18.9** 18.4
40	1 Mile N. Brooks......		.....	.14	2.00	32.40	39.00	4.68	1.00	1.94	.34	1.84	16.90	100.24	176	5.0 7.0 9.3 10.9 12.5	183. 234. **234.** 227.	60. 79. **105.** 105. 102.
41	1 Mile N. Brooks......	....	.....	.50	2.70	30.98	30.04	4.40	1.24	2.28	.34	2.34	25.36	100.18	....	5.0 6.5 8.7 11.1 13.3	169.(1) 243. 259.(4) 296. **318.**(5)	61. 71. 104. **117.** 67.
42	Just S. of Stafford Court House	....	.....	.08	.28	.94	2.38	6.04	5.48	46.30	4.00	6.70	27.86	100.06	....	7.0 9.0 10.7 11.4	**338.** 336. 334.	19.6 22. **22.7** 17.8
43	W. of Quantico.	....	.....	.....	.14	4.00	42.20	20.84	2.74	4.38	.84	3.58	21.00	99.72	....	5.3 6.0 7.0 8.0 9.0	Too dry 357. 371. **388.** 377.	**80.6** 75.0 71.7 68.7 58.2
44	Near Mouth of Aquia Creek	....	.....	1.10	2.04	4.68	7.60	8.98	6.14	40.78	5.00	6.98	16.50	99.80	....	5.0 7.0 8.0 8.6 10.0	**243.**(1) 233. ...... 208.	...... 17.4 **20.4** 19.5 18.0
45	½ Mile S. E. Stafford Court House.	....	.....	Tr.	.14	1.20	3.14	7.58	4.78	52.14	5.50	5.24	20.80	100.52	....	5.0 7.0 10.0	**264.**(6) 257. 245.	20. **22.2** 21.6
46	2 Miles E. Fredericksburg	....	.....	.34	.18	.24	1.48	13.00	10.34	34.24	4.00	8.50	27.56	99.88	1736	4.3 6.4 8.0 11.0	235.(1) 320. **339.** 324.	...... 21.2 **21.6** 20.0

(1) Too dry. (2) Dry, hard to temper. (3) Very wet.
(4) Damp and sticky. (5) Much too wet. (6) Nearly too dry.

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
47	½ Mile N. W. King George	....	....	....	.04	.14	15.90	36.88	10.58	16.24	1.08	3.90	15.56	100.32	736	4.0 6.0 8.0	185.(1) **197.** 165.	70.0 **71.3** 70.5
48	6 Miles S. Fredericksburg	....	.32	5.82	13.95	40.90	28.40	5.32	1.09	2.19	.25	.55	.....	98.79	208	0	......	358.
49	Fredericksburg	....	9.05	30.15	20.17	28.87	10.55	1.17	.13	.10	.....	.02	.....	100.21	72	0	......	780.
50	Fredericksburg	....	.37	4.82	9.57	52.00	31.15	1.54	.14	.10	.05	.05	.....	99.79	72	0	......	780.
51	Fredericksburg	....	1.45	7.47	10.20	43.02	29.99	4.54	1.00	1.65	.19	.32	.....	99.83	304	0	......	300.
52	2 Miles N. Milford......	Iron and Brass Molding.	....	.20	.10	.10	.14	5.00	12.60	66.38	2.94	3.10	8.90	99.46	1304	2.0 4.3 6.3	Too dry **154.** 117.	53. **55.5** 55.5
53	Norfolk.......	....	....	1.00	3.25	35.15	39.32	15.87	2.00	1.70	.09	.15	.....	99.83	8	0	......	138.
54	Cape Henry...	Cores....	....	....	1.22	24.84	67.09	6.10	.39	.16	.....	.09	.....	99.84	8	0. 2. 4. 6.	...... (2)	300. **595.** 589. 459.
55	CapeHenry...	Cores....	....	....	.52	11.22	61.77	21.00	2.35	2.59	.09	.07	.....	99.61	40	0. 2. 4. 6.5	...... (2)	167. **333.** 333. 266.
56	Willoughby Spit, Norfolk	....	....	6.57	27.42	52.82	11.94	.....	.....	.....	.....	.....	.....	98.75	40	0	......	850.
57	Dismal Swamp	....	....	.37	.49	1.89	17.59	49.59	14.92	12.09	.59	2.04	.....	99.57	240	0	......	61.
59	Franklin......	....	....	....	.04	2.47	89.57	3.04	3.90	.20	.....	.55	.....	99.77	.....	0	......	119.
60	Mt. Airy......	Molding..	....	....	....	....	.18	3.90	13.88	67.28	2.60	2.88	8.26	98.98	....	2.0 4.0 6.0 8.5	Too dry **199.** 164.	48.3 51.5 **60.0** 37.2
61	Richmond.....	Molding and Cores	....	....	....	....	....	....	....	....	....	....	....	....	2404	3.9 6.2 7.8 9.8	200. **207.** 194.	273. 273. **300.** 178.
62	S. E. of Disputanta..	....	....	10.14	16.04	30.00	13.58	2.34	.68	1.14	.14	1.08	24.80	99.94	....	7.0 8.0 9.0 12.0 14.0	241. 329. 335. **342.** Too wet	**288.** 242. 222. ....
63	Monroe Bridge, S. of Franklin	....	....	.08	.08	.22	.80	16.96	39.60	21.14	11.52	4.70	4.76	99.86	304	0 6.0 8.0 9.9	...... 76. 82. **102.**	82. 77. **88.** 55.
64	Nottoway River.......	....	....	.02	.....	.70	4.55	30.05	13.99	33.09	3.55	13.82	.....	99.77	.....	0	......	32.
65	ScotlandYard.	Molding Sand...	....	....	.....	.40	16.70	42.50	13.94	13.68	.58	1.54	10.32	99.66	....	2.5 4.5 6.0	**247.** 218. 155.	**106.** 103. 94.2
66	Coggins Point..	....	....	....	.38	1.30	4.54	15.58	10.48	41.28	2.48	6.54	16.42	99.00	....	6.0 7.6 8.0 9.5 12.2 12.3 13.6	213. 275. 303. 303. 303. **306.** 243.	.... 15.15 15.75 17.20 **17.30** 7.7
67	Providence Forge........	Fino Oil Core Work....	....	.38	1.58	10.04	36.50	23.10	6.00	12.00	1.20	3.00	5.00	98.80	140	0 4.0 6.0 8.0	...... 80. **83.** 81.	32. 105. **122.** 108.
68	Providence Forge........	....	....	.18	.65	4.79	40.15	33.72	.41	15.74	1.55	3.08	.....	100.27	.....	0	......	67.
69	Providence Forge........	....	....	.22	1.10	6.97	66.22	(3)	7.09	12.62	1.47	3.44	.....	99.13	172	0	......	40.

(1) Too dry. (2) Bars very weak. (3) Included with sand on 70 mesh screen.

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
70	Boulevard P. O........	Core.....	5.47	15.29	16.70	32.80	22.62	4.80	.65	.77	.....	.47	.....	99.57	40	0	326.	326.
71	Just E. of Boulevard P. O........	Molding Sand...	.....	.....	.....	.14	2.20	19.10	24.00	38.84	1.44	2.50	11.80	100.02	1376	2.5 4.0 6.2	Too dry **222.** 203.	54.1 **54.6** 54.3
72	Just E. of Boulevard... P. O........	....	.....	.....	.04	.14	9.40	25.20	18.24	24.68	1.00	2.00	19.20	99.90	2208	4.0 6.0 6.5 8.0 11.0	300 (1) 310. 315. **316.** 250.	55.0 **57.7** 55.7 51.0 ......
73	½ Mile S. E. Diascund Bridge......	....	.....	.....	.15	2.07	18.27	21.30	13.84	41.45	1.15	1.45	.....	99.68	272	0	......	56.
74	Yorktown Just S. of Williamsburg	....	.....	.....	1.00	1.18	41.94	34.68	3.56	3.10	.44	1.70	13.46	101.06	1040	3.5 6.0 9.5	199. **208.** 145.	**112.** 95.7 ......
75	Scrimmin's Creek.......	....	.....	.....	.....	.14	7.18	54.28	19.54	11.34	.14	.96	6.00	99.58	736	2.0 3.0 4.0 6.0	111. **120.** 112. 96.	...... 115.8 **118.0** 111.0
76	Scrimmin's creek........	....	.....	.....	.....	.10	6.24	51.08	20.74	10.20	.48	1.10	9.40	99.34	....	2.0 4.0 6.0	Too dry **208.** 158.	96.8 **98.5** 92.5
77	1½ Mile N. W. Peeke's Turnout.....	....	.....	.60	.24	.80	1.74	18.98	20.28	33.34	1.30	4.14	18.26	99.68	....	2.3 4.8 6.5 9.0 10.0 12.0	Too Too **284.** 284. 279. 266.	dry dry 28.3 **31.05** 29.9 ......
78	8 Miles N. W. West Point..	....	2.64	11.10	14.20	32.10	18.84	2.70	.38	.48	.04	.04	16.96	99.48	....	5.0 6.0 7.0 9.5	Too dry 330. **348.** 333.	**327.** **327.** 270. 185.
79	Urbana.......	....	.....	.....	.08	17.44	59.68	4.08	.48	.84	.10	.72	15.70	100.02	....	3.0 3.5 6.0 8.0	...... 208.(2) **298.** 278.	240. **258.** 233. 157.
80	Center Point...	....	.....	.10	.08	.30	3.30	38.04	15.64	23.04	1.04	3.14	15.00	99.68	....	3.9 6.2 8.1	212. **233.** 203.	56.4 **63.2** 50.6
81	¾ Mile W. Miford.......	....	.28	.24	1.00	.20	.40	2.60	7.80	65.30	4.58	4.40	12.86	99.66	....	2.0 3.0 4.0 6.0	Too (2) **172.** 155.	dry 31.90 **33.2** 31.6
82	4 Miles from Milford.......	....	.54	1.98	2.10	4.90	37.14	24.84	3.00	2.94	.20	.80	21.66	100.10	....	5.0 6.5 7.0 9.0	Too dry (2) **322.** 296.	62.6 97.4. **106.** 90.2
83	Cash Corners..	....	.....	.....	.10	.08	.14	.38	2.44	55.10	13.70	12.94	15.10	99.98	....	3.0 4.5 7.0	Too dry **228.** 202.	**25.8** 23.7 22.7
84	Cash Corners..	....	.....	.07	Tr.	Tr.	Tr.	Tr.	Tr.	48.08	7.34	15.64	28.80	99.93	....	7.0 9.0 10.5 12.0 12.4 16.0	...... 218. **243.** 229.	5.76 6.12 7.92 8.91 10.0 **12.2**
85	½ Mile S. E. Mouth of Potomac Creek.......	....	.....	.20	.24	.98	9.18	20.70	1.30	43.90	4.00	6.14	13.36	100.00	....	3.0 5.0 6.0 8.0 9.4 11.0	Too **273.** 250. 230. 222. 212.	dry 28.0 **31.2** 29.2 23.9 ......

(1)Almost too dry. (2)Too dry.

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test												Dye Adsorption	Water Per Cent	Bond Strength	Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total				
86	2½ Miles from Montross....	....	.....	.84	.44	.48	.98	3.78	3.78	36.94	8.54	20.64	23.60	100.02	....	7.0 9.4 11.0 12.0 14.0 16.6 16.9 19.0	...... 175. 184. 213. 213. 214. **228.** 213.	4.4 5.2 5.8 6.1 6.4 **8.8** **8.8** 7.7
87	Fredericksburg	....	.....	.....	.14	.40	1.00	3.34	.14	62.18	5.54	7.78	19.58	100.10	....	4.7 6.3 8.0 9.7	...... 226. **227.** 195.	21.4 **21.6** 20.7 ......
88	5 Miles S. E. Fredericksburg	....	1.50	2.44	1.50	1.78	4.08	4.40	3.64	56.80	5.14	7.98	10.74	100.00	....	4.5 6.0 8.0	168. **169.** 157.	23.1 **23.3** 23.1
89	Alexandria.....	Iron Molding	.....	.....	.08	.08	.98	2.88	2.64	24.58	8.14	32.48	27.92	99.78	1376	5.0 7.0 9.0 10.0	192. **210.** 185.	5.4 9.2 9.25 **11.8**
90	Alexandria.....	Coarse Work and Cores...	.....	.....	.....	.....	11.30	31.14	9.24	20.40	2.44	6.24	18.92	99.68	1072	4.0 5.0 6.4 8.7	Too 200. **227.** 207.	dry **48.** 44. 44.
99	Petersburg....	Dixie Core Sand...	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	....	4.4 5.0 6.7 8.0 10.3	...... 214. 218. **226.** 192.	406. 415. **435.** 324. ......
100	Richmond.....	Steel Sand	.....	.50	.80	2.38	3.74	24.14	23.20	31.60	1.60	2.30	9.72	99.98	....	2.0 3.4 5.0	137.(1) **163.** 142.	82.7 **84.1** 76.3
307	Scottsville.....	....	1.07	1.84	3.60	11.95	67.75	9.55	2.39	.66	.40	.83	.....	100.04	72	0	......	160.
308	Stapleton......	....	.....	.15	1.00	2.40	15.42	22.67	19.85	12.36	11.05	14.62	.....	99.32	72	0	......	16.2
309	Lynchburg....	....	1.81	7.10	7.15	32.29	44.47	5.23	1.32	.36	.22	.35	.....	100.30	64	0	......	265.
310	Lynchburg....	....	.20	.88	.66	2.58	14.04	11.34	8.68	5.74	5.82	8.72	41.30	99.96	504	4.2 6.2 7.8 9.3 12.0 13.0 15.0	147. 207. 218. **238.** 225.	2.4 2.2 4.4 15.7 44.0 **72.0** **Wet**
312	Chatham......	....	1.70	8.30	13.35	17.32	53.15	4.80	.80	.15	.09	.25	.....	99.61	72	0	......	369.
313	Danville......	....	3.67	12.72	13.80	33.67	30.65	3.85	1.02	.25	.12	.22	.....	99.97	72	0	......	267.
314	Danville	....	2.57	12.15	18.70	42.32	22.70	1.12	.25	.07	.05	.22	.....	100.15	72	0	......	618.5
315	Danville	....	.09	.52	.57	1.45	30.94	36.65	15.54	6.42	3.50	3.72	.....	99.40	404	0	......	54.
318	Salem.........	Cores.....	.39	1.60	3.19	6.20	49.82	14.07	8.52	5.17	5.25	5.84	.....	100.05	304	0	......	29.5
323-I	Delton........	Molding Sand...	.22	.50	.42	2.98	26.40	12.64	5.90	2.84	3.18	7.34	37.96	100.38	....	6.0 7.6 11.0 14.0 15.4	195. 244. 284. **367.** 316.	17.3 17.3 **49.0** 36.0 18.4
224	Delton.........	....	.....	.04	.15	1.95	45.70	27.27	11.49	5.05	3.60	4.05	.....	99.30	176	0	......	46.5
326	Petersburg....	Molding Iron....	1.20	3.50	7.30	20.44	22.18	10.78	6.78	3.98	3.80	5.60	15.90	101.16	904	4.0 6.0 8.0 9.7	209.(1) **283.** 225.	34.0 80.0 **133.0** 80.0
329	Kermit.........	....	.....	.....	.09	4.50	64.10	21.79	6.42	1.78	.55	.34	.....	99.55	40	0	......	105.
330	Kermit.........	....	.....	.01	.40	2.64	68.84	17.96	6.40	2.15	.85	.29	.....	99.54	40	0	......	126.
331	Kermit.........	....	.....	.35	21.86	65.90	6.54	2.61	.96	.52	.33	.29	.....	99.36	32	0	......	963.4
332	Silica..........	....	.....	.....	.10	5.56	63.27	21.77	5.86	1.22	.64	1.16	.....	99.61	40	0	......	93.

(1) Too dry.

VIRGINIA

Lab. No.	Locality	Grade if Used	Fineness Test: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay Substance	Total	Dye Adsorption	Water Per Cent	Bond Strength	Permeability
333	Silica........	....	.41	1.94	1.85	15.45	54.38	18.51	4.64	1.01	.55	1.04	.....	99.79	40	0	......	91.
334	N. Holston....	....	.50	2.02	11.44	16.36	12.54	4.02	2.74	1.62	2.00	11.60	35.80	100.64	936	4.2 6.4 7.5 10.2 14.8 17.0	130. 175. 261. 258. ...... Too wet	1.4 1.7 2.4 4.9 20.0 ......
336	Wytheville....	....	.66	.96	1.94	18.14	41.94	11.89	5.18	3.08	2.28	3.64	10.92	100.58	472	0 2.6 3.8 5.9 6.8	...... Too dry 166. 117.	29. ...... 105. 133. 117.
337	Pearisburg.....	....	13.89	31.45	21.60	14.67	11.80	3.52	1.52	.55	.45	1.00	.....	100.45	72	0	......	145.
338	Pearisburg.....	....	.....	.42	.88	8.40	39.68	18.84	9.62	4.38	3.88	6.38	7.60	100.08	208	0	......	16.9
339	Pearisburg.....	....	.....	.86	1.38	13.80	41.68	16.10	7.60	2.96	3.18	4.92	7.58	100.06	208	0	......	16.5
340	Eggleston......	....	.....	.....	.06	2.20	53.56	21.80	9.00	3.48	2.26	3.10	4.48	99.94	208	0	......	56.
342	Buena Vista...	Iron Casting Some Brass....	.....	.14	1.14	2.58	16.36	13.78	10.98	8.40	10.14	12.68	24.26	100.46	936	4.0 6.0 7.7 10.0 12.0 14.0	187. 220. 234. 242. 210.	6.5 9.4 19.0 27.0 28.0(1) 1.4
344	Basic..........	Iron Casting..	.22	.16	.16	1.70	19.42	15.48	13.38	9.24	9.60	9.84	21.16	100.36	1008	4.0 6.7 7.6 10.4 12.9	Too dry 200. 189. 196. 184.	6.5 10.7 12.6 20.0 19.0
346	Goshen........	....	.....	.....	.19	6.43	65.20	22.32	4.61	.61	.22	.15	.....	99.73	.....	0	......	139.
348	Winchester....	....	.....	.....	.14	3.16	49.16	22.68	9.34	3.54	2.62	2.28	6.70	99.62	544	0	......	50.5
349	Lipscomb......	....	.....	.06	.22	.42	79.88	7.72	2.44	.90	.64	1.20	6.60	100.08	344	0	......	95.5
351	Clifton Forge..	Molding..	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	......	1136	4.0 6.0 8.0 10.0 12.0 14.2	Too dry 270. 342. 312.	7.0 16.7 20.0 36.0 33.4 33.4
352	Port Republic .	Iron Casting..	.....	.04	.20	.38	11.08	10.88	14.12	10.78	12.52	15.50	24.94	......	704	4.0 6.0 8.0 9.3 11.3 13.1	Too dry 167. 185. 179.	5.0 10.3 15.7 18.4 25.8 25.8
353	Elkton........	Iron Molding.	.....	.04	.06	.36	6.66	11.36	11.68	7.64	8.80	11.62	41.76	......	1672	4.0 6.0 8.0 10.0 11.5 14.0 15.4	Too dry 224. 351. 334.	3.7 4.9 9.0 14.7 20.0 31.0 11.0

(1) Too wet.

Resources of Illinois Foundry Sands

By M. S. Littlefield, Urbana, Illinois

An investigation of the molding sand resources of Illinois was recommended to the Illinois Geological Survey by the Joint Committee of the American Foundrymen's Association and the National Research Council as a part of their program to secure data on the molding sand resources of the important foundry states of the Union. Illinois which ranks third in the production of molding sand and fifth in the number of foundries is of considerable importance both as a producer and as a consumer. There are 490 active foundries of all types in the State.[1] Much of the production is silica sand for steel founding, a branch of production which is well established. The production of molding sand for the years 1922 and 1923 was as follows:

	Steel sand	Natural bonded sands	Total	Natural bonded sand
	Tons	*Tons*	*Tons*	*Per cent*
1922...........	546,765	107,996	654,761	16.5
1923...........	647,963	150,720	798,683	18.9

Visits to foundries showed that considerable sand is shipped in from outside the State. For the foundries visited in Chicago more than 50 per cent of the sand was imported and for those located elsewhere in the State approximately 10 per cent was obtained outside Illinois. Of the State's 490 foundries, 200 are located in Chicago. If the percentages given above hold true, about one-fourth of the natural bonded molding sand used within Illinois is obtained from other states. It is probable that the greater part of the sand shipped in is fine sand.

The resources of commercial natural bonded molding sand are estimated to approximate at least 6,000,000 tons exclusive of the sands of the St. Peter formation, and of the limy yellow silts known geologically as loess in the western part of the State.

[1]The Foundry, p. 801, October 15, 1924.

Editor's Note: This report is virtually a copy of Report of Investigations No. 3 of the Illinois Geological Survey, under whose auspices the field investigation of Illinois molding sand resources was conducted. The laboratory tests were made by the Engineering Experiment Station of the University of Illinois and the Illinois Geological Survey cooperatively. The inclusion of this material in this volume is by the courtesy of the cooperating parties.

There are several million tons available in the Wabash valley at points three to five miles from railroads which were not sampled nor included in the estimates as being commercial.

The sand resources of the State may be roughly divided into two classes:—(a) the fine, and (b) the medium and coarse sands. The latter are abundant and probably will furnish a sufficient supply for many years. The fine sands, that is, those which are of usable quality, are not so abundant. The loess or the calcareous yellow silt, which is found in such abundance along the bluffs of Mississippi River and for some miles to the east, does not seem to be worthy of consideration as a competitor for lime-free sands of the same texture. It is used for some purposes and it is regretful that because of its abundance and uniformity it cannot be further utilized.

METHOD OF INVESTIGATION

Field Work

GENERAL STATEMENT

Field work was carried on from June 18 to September 15, 1923. Eighty-five counties of the 102 counties of the State were studied, those omitted being counties from which there has been no production reported and whose geological conditions indicate that they are barren territory. A total of 139 samples was collected and tested, 57 from producing pits, 42 from new deposits, and 40 from foundries. The 40 samples collected from foundries included 24 Illinois sands and 16 foreign sands. All the known producing pits in Illinois were visited. Twenty-nine new deposits of commercial promise were found and sampled.

In order that the study should be conducted as nearly as possible from the viewpoint of the foundryman, 40 foundries were visited in Chicago, Peoria, East Moline, Rock Island, East St. Louis, Quincy and other cities. A study was made of foundry practice, information was obtained regarding their molding sand problems, data were secured on sand production in Illinois and importation from other states, and samples of sands, which had been found to be satisfactory from the stand-

point of actual foundry practice, were collected with a view to testing these and using the results for checking the quality of "unknown" sands.

SAMPLING METHODS

Samples of molding sand were obtained from three general sources—the foundry bins, from pit sections or partially loaded cars at the pits, and from dug sections of undeveloped outcrops. Samples taken from cars were selected from various parts of the car and carefully mixed. These included produced grades. A few produced grades were taken from the pit section, care being taken to include exactly that part of the section being dug. Most samples mixed from pit sections are called possible grades as there is sufficient sand in position to produce a like grade. There are, however, some types of deposits which are so variable that large quantities of a given grade are difficult to obtain.

The producers' grade classification is given in Tables 1 and 2 only in case the producer definitely stated that the grade was standard. Also it cannot be assumed that all produced grades or possible grades can be produced so that test results would be exactly the same as those given in this report. In order that sands can be bought on a basis of standard tests, they must be produced by controlled methods and purchasing plants must observe a reasonable degree of tolerance. A discussion of types of sands will be included in the forthcoming more detailed report on the molding sand resources of the State by the Illinois Geological Survey.

LABORATORY WORK

The testing of the samples collected during the summer of 1923 was done cooperatively during the summer of 1924 by the Engineering Experiment Station of the University of Illinois and the Illinois Geological Survey, in the foundry laboratory of the department of Mechanical Engineering. The equipment in this laboratory is as specified in the Standard Test Procedures recommended by the American Foundrymen's Association and the results are therefore comparable with the results of other organizations using the standardized tests. In addition, base permeability tests, with the clay removed, were made on all the

sands, and durability tests which gave the percentage of a bond strength lost by heating for two hours at a temperature of 600 degrees Fahr., were made on 48 sands.

ACKNOWLEDGMENTS

The success of this scientific study has been dependent in large measure on the interest and cooperation of the molding sand producers and foundrymen of the State. Attention given by the Chicago Foundrymen's Association and the Quad City Foundrymen's Association enabled the visitation of more plants than would have been otherwise possible.

Dr. M. M. Leighton, Chief of the State Geological Survey, was in constant touch with the work, and his detailed knowledge of the glacial deposits of northern Illinois made possible a systematic survey of difficult areas; Mr. L. F. Athy, of the University of Chicago, ably assisted in the field work; Mr. B. W. Benedict, Manager of the Shop Laboratory, provided full laboratory facilities; Mr. R. E. Kennedy, assistant secretary of the American Foundrymen's Association, gave helpful advice during both field and laboratory work; Professor C. W. Parmelee, Head of the Department of Ceramics, extended aid in pursuing experimental work on heat tests; Mr. H. W. Dietert, Sand Technologist of the United States Radiator Corporation, Detroit, suggested practical test procedures from his own experience; and in the laboratory, Mr. R. S. Datta and Mr. B. F. Nordmann of the University of Illinois were helpful assistants by reason of their scientific interest.

RESULTS OF TESTING

Introduction

Tables 1 and 2 contain in summary form the results of testing the entire number of samples. The tests for fineness, permeability, and bond were carried on in accordance with recommendations of the American Foundrymen's Association.[2] Tests for

[2]Tentatively adopted methods of tests and resumé of activities of the Joint Committee on Molding Sand Research. American Foundryman's Association bulletin, June 1, 1924 (Corrected edition).

durability and base permeability were made with a view to presenting results of possible practical value to foundrymen. These results should stimulate work which will check their value as practical and feasible tests. Modifications of the methods might well be made but it is desirable in all cases to use as much of the standard test apparatus and ordinary foundry equipment as possible.

Durability Test

VALUE

A need for a test of the durability of molding sand has been evident, as a sand which has a low degree of durability may not be profitably used even though the fineness, permeability and cohesiveness tests indicate its suitability. The problem of durability, or life of a sand, is distinct from the problem of refractoriness or resistance to fluxing, as it is conceivable that a very refractory sand might be short lived. The general procedure of durability tests developed and used in plant control work by H. W. Dietert was adopted after some experimentation with temperatures at 500 degrees, 600 degrees, 1000 degrees to 1250 degrees, and 1800 degrees Fahr. A temperature of 600 degrees Fahr., which is that used by Mr. Dietert, was found to be best suited for obtaining results apparently indicative of durability. Lower temperatures gave little differentiation between sands, and temperatures above 1000 degrees appeared to dehydrate so much of the clay substance that the bond strength was due largely to interlocking of grains and possibly some adhesion between grains which had burnt on coats of "dead" clay. At 1800 degrees the bond strength was entirely lost in the few samples tested at that temperature.

The foundry problem of durability relates to the partially burnt sand which goes back into the heap and not to the sand which is entirely burnt out and discarded. Hence it is desirable to know the loss of bond strength at low temperatures. Such a test is largely an aid in gaging the durability of new sand.

GENERAL PROCEDURE

Three pounds of untested, air dried sand broken up to pass a No. 6 riddle, is put into a sheet iron or aluminum pan

of such size that the sample may be spread evenly in a layer about one-fourth of an inch thick. The sand is placed in a gas core oven which is heated until a given shelf reaches 600 degrees Fahr. and a thermo couple laid on top of the sand. Uniform temperature is maintained for two hours, a tolerance of 15 degrees Fahr. being allowed after the sand reaches 600 degrees Fahr. After being removed from the oven, the sand is spread in a thin layer on an iron core bench and allowed to cool for two hours. It is then tempered to the optimum water content for bond strength and allowed to temper for twenty-four hours. The test for bond strength is made in accordance with the procedure of the standard cohesiveness test. The difference between the bond strength of the heated sample and the bond strength at optimum water content of the usual sample is the loss which is best stated as percentage of the maximum bond strength of the sample.

The durability bond test figures given in Tables 1 and 2 were obtained at the optimum water content as shown by the usual test. Quite probably the optimum water content changes somewhat on heating and although no specific data can be advanced in support, it seems probable that excessively high or excessively low bond strength losses may be due in part to migration of the optimum water content. The weight of this factor must be established or eliminated before a test showing low durability be condemned or one showing a high durability or a slight gain be accepted with full confidence. Foundry practice is the final judge in weighing the value of any test and a check by plant control men on the life of the sands in present use would be of considerable advantage.

Base Permeability

VALUE

Base permeability tests were found to be of practical value by H. W. Dietert in furnishing data on the tendency of certain sands to open or close a heap. The natural permeability of the sand, that is, the permeability when tempered for use, gives little

or no indication as to the effect of the sand grains upon the permeability of a heap after all or a part of the clay is burnt out. The variations of base permeability from natural permeability are striking in some cases. Correlation of such results with the action of a sand in the heap is the final criterion of the value of these data. It seems that, like the durability test, this test is most valuable in testing new sands.

GENERAL PROCEDURE

Approximately three hundred grams of sand are treated in the same manner as for the fineness test, in order to eliminate the clay. The dried sand is poured through a funnel into a two-inch glass tube, upon which is a mark indicating the volume of sand that forms a two-inch column when rammed in the permeability cylinder. The quantity of sand necessary varies slightly with certain sands according to their degree of compaction. A screen, 200-mesh for fine samples and 100-mesh for coarser samples, is used in the end of the permeability cylinder. The sand in the glass tube must be examined for bedding into laminæ of various sized grains, particularly the silt and serves as an indicator of the difficulty involved in obtaining a uniform mix of all grades. The sand is poured evenly from the glass tube into the permeability cylinder. Some sorting is inevitable with some sands and experience will teach a rate of pouring that will minimize this error. Care must be taken not to jar or "shake down" the sample before ramming. A screen on the upper surface is advisable. The permeability is obtained by the standard method. The sand is returned to the original receptacle and another sample, taken from the remixed total sample, is tested. Sorting of grain sizes by pouring the sand into the cylinder is a serious difficulty and may produce a silt layer which is more impermeable than the sample as a whole. A check as definite as is obtained in natural permeability tests is seldom possible, if the same tolerance of height of sand cylinder is used. At least five runs should be made to obtain a fair average.

CONCLUSIONS

Results showed that the silt grade is the most important of the factors governing base permeability. It is probable that there is a "saturation point" at which the material on 270-mesh and through 270-mesh occurs in sufficient quantity to fill all the interstices between the larger grains. Such a point is high if the sand is coarse, well sorted and rounded in shape, and lower if several grades of angular sand are present. If the silt does not completely fill the interstices, the sand may be as open or more open than when tempered. However, if the silt does fill all the interstices, the sand will probably be less permeable than when tempered. Probably no practical mathematical method for computing base permeability from the grain size grade percentages can be devised. However, after some experience, it is entirely possible that a general prediction of a high or low base permeability might be determined from the fineness test data. The only way to be certain is to make the test, which can be made at the same time as the fineness test.

DESCRIPTION OF MOLDING SAND DEPOSITS IN ILLINOIS

Adams County

Sample No. 139: NE. 1/4 NW. 1/4 sec. 26, T. 1 S., R. 9 W. One-fourth mile north of Chicago, Burlington and Quincy siding. Sample taken from bin of Electric Wheel Company, Quincy, Illinois. From producing pit worked by J. A. Platt, Quincy, Illinois. Used for light gray iron and for bond renewal. Three- to seven-foot section. Extent, 20,000 to 100,000 tons. Formation, wind blown silt or loess, capping east valley wall of Mississippi River. A calcareous sand containing primarily deposited bond.

Bond County

Sample No. 52: Location same as No. 171. Sample taken from bin of Greenlee Brothers, Rockford, Illinois. Used for heavy castings.

Sample No. 53: Location same as No. 171. Sample taken from bin of Greenlee Brothers, Rockford, Illinois. A finer grade than No. 52. Used for medium heavy castings. Mixes made of No. 52 and No. 53 to suit grade of work.

Sample No. 100: Location same as No. 168. Sample taken from bin of Frank Foundries, Moline, Illinois. Used for very heavy castings. Trade name, Greenville Coarse.

Sample No. 166: NW. 1/4 NE. 1/4 sec. 25, T. 4 N., R. 2 W. One and one-half miles east of Tamalco siding, Chicago, Burlington and Quincy Railroad. Worked by G. Nicol and Son, Collinsville, Illinois. Production for heavy gray iron work. Sample mixed in pit. Half and half mixture of heavy top sand and sharp basal sand. Extent, 100,000 to 280,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Sample No. 167: Location same as No. 166. Sample of produced grade from 7-foot pit section. Shipped for heavy gray iron work.

Sample No. 168: SW. 1/4 NE. 1/4 sec. 1, T. 5 N., R. 2 W. One and one-half miles south of Mulberry Grove siding of Vandalia Railroad. Worked by Warren Sand Company, Mulberry Grove, Illinois. Production for heavy gray iron work. Sample taken from two partially loaded cars. Pit section 7 to 9 feet. Extent, 100,000 to 200,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Sample No. 170: E. 1/2 SW. 1/4 sec. 10, T. 5 N., R. 3 W. One-half mile northwest of Greenville siding of Vandalia Railroad. Worked by W. M. Peterson and Sons, Greenville, Illinois. Production for heavy gray iron work. Pit section 3 to 8 feet. Sample of produced grade taken from partially loaded cars. Extent, 120,000 to 200,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Sample No. 171: S. 1/2 SW. 1/4 sec. 2, T. 5 N., R. 3 W. One and one-fourth miles north of Greenville siding of Vandalia Railroad. Worked by Ed. E. Squier Company, Federal Reserve Bank Building, St. Louis, Missouri. Production for heavy gray iron work. Sample from several channels in total 7-foot pit section. Extent, 100,000 to 300,000 tons. Formation, Illinoian fluvio-glacial sand containing weathered bond.

Sample No. 179: Location same as No. 166. Sample taken from bin of Enterprise Foundry Company, Belleville, Illinois. Used for heavy gray iron work.

Boone County

Sample No. 43: Center E. 1/2 sec. 26, T. 45 N., R. 4 E. Three miles south of Capron Station of Chicago and Northwestern Railroad. Unworked deposit. Owner's name unknown. Sample from several channels in total 3-foot section exposed in creek bank. Extent, 20,000 to 40,000 tons. Locality favorable for similar deposits. Formation, stream terrace deposit. Sand contains weathered bond.

Bureau County

Sample No. 113: SW. 1/4 sec. 21, T. 16 N., R. 8 E. One mile southeast of Wyanet sidings of the Chicago, Rock Island and Pacific and the Chicago, Burlington and Quincy railroads. Worked by Golden and Larson, Wyanet, Illinois. Sample from several channels of 3- to 4-foot pit section. Same as produced grade. Used for light and medium gray iron work. Extent of deposit, 160,000 to 400,000 tons. Formation, wind blown sand containing weathered bond. Mantled by 1 1/2 feet of leached silty clay, a part of which is added to increase bond. Produced sand a combination of weathered bond and primary bond sand.

Sample No. 114: NE. 1/4 NE. 1/4 sec. 32, T. 16 N., R. 7 E. One and one-half miles northwest of Buda siding of Chicago, Burlington and Quincy Railroad and one-fourth mile west of Chicago and Northwestern Railroad. Producing pit worked by Mr. Lay, Buda, Illinois. Sample taken from several channels of 3 1/2-foot pit section. Similar to produced grade. Sand used for light and medium gray iron work. Extent, 40,000 to 200,000 tons. Formation, wind blown sand containing weathered bond. Capped by one-foot layer of silty clay. Very little top clay added to this sample.

Sample No. 115: Location same as No. 114. Sample taken from loaded car. A heavier grade than No. 114, produced from same weathered bond sand in addition to the silty clay capping.

Sample No. 116: NW. 1/4 sec. 35, T. 16 N., R. 7 E. One mile east of Buda siding of Chicago, Burlington and Quincy Railroad. Worked by Jesse Westervilt, Buda, Illinois. Sample of produced grade, taken from several channels in 3-foot pit section. Used for medium gray iron work. Extent, 60,000 to 90,000 tons. Formation, wind blown sand containing weathered bond. Capped by one foot of leached silty clay. Practically no clay added to sample. Heavier grades may be produced by addition of silty clay.

Sample No. 117: Location same as No. 116. Sample taken from single hole dug into upper two feet of 3 1/2-foot section 200 yards from pit face. Similar in texture to No. 116.

Cass County

Sample No. 138: Location same as No. 143. Sample taken from bin of Electric Wheel Company, Quincy, Illinois. Used for medium gray iron.

Sample No. 143: Sec. 20, T. 17 N., R. 11 W. One-half mile to Arenzville siding of Chicago, Burlington and Quincy Railroad. Worked by G. Nicol and Son, Collinsville, Illinois. Sample from several channels in coarsest phase. A possible grade. Extent of entire deposit 50,000 to

120,000 tons. Formation, wind blown sand containing weathered bond. Mantles lower portion of slope of east valley wall of Illinois River. Some parts of section contain finer and coarser material interbedded and hence some produced sands are combinations of weathered bond and primary bond sands. The primarily bonded fine sands and silts which occur high on the slope are calcareous.

Sample No. 144: Location same as No. 143. Sample taken from several channels of finest producible sand seen in this pit. Sold for light gray iron and stove plate.

Sample No. 145: Location same as No. 143. A different pit face with a 5 1/2-foot section. Upper 4 feet lime-free; lower 1 1/2 feet contain lime concretions. Whole pit face worked for produced grade. Sample taken from several channels in upper 4 feet of section.

Sample No. 146: Location same as No. 143. Sample from lower 1 1/2 feet of pit section noted under No. 145 is very calcareous and of no value for molding sand. This part of section should be kept out of produced grades.

Sample No. 147: NE. 1/4 NW. 1/4 sec. 27, T. 18 N., R. 11 W. One-eighth mile east of Bluff Springs siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name not known. Sample taken from several channels in 2- to 4-foot section exposed in roadcut. Extent 14,000 to 35,000 tons. Origin of sand same as deposit listed under No. 143. Finer textural phases shown. Sample is mixture of some weathered bond sand with much primary bond sand. Such a mix gives low permeability.

Sample No. 177: Location same as No. 143. Sample taken from bin of Eagle Foundry Company, Belleville, Illinois. Used for stove plate.

Clinton County

Sample No. 197: No data on location. Sample sent in by Erne H. Duckman, Keyesport, Illinois.

Cook County

Sample No. 10: NE. 1/4 SW. 1/4 sec. 9, T. 42 N., R. 9 E. Five miles southwest of Barrington. Unworked deposit. Owner, Henry Louis. Sample taken from several channels of total 3-foot section. Overlain by 3 to 4 feet of sharp sand. Extent, 12,000 to 20,000 tons. Locality favorable for similar deposits. Formation, wind blown sand, capping hilltop. Contains weathered bond.

Fayette County

Sample No. 37: Location same as No. 164. Sand from same part of deposit as No. 164. Sample taken from bins of National Malleable Company, Chicago, Illinois. Used for heavy castings.

Sample No. 161: SW. 1/4 SW. 1/4 sec. 32, T. 7 N., R. 1 E. Adjacent to siding on spur of Illinois Central Railroad. Unworked deposit. State Prison Farm, Vandalia, Illinois. Sample from single channel of total 9-foot section. Extent, 50,000 to 200,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Sample No. 162: Location same as No. 161. Sample from several channels in upper 5 feet of total 9-foot section.

Sample No. 163: SW. 1/4 NW. 1/4 sec. 32, T. 7 N., R. 1 E. One-eighth mile from siding of Illinois Central Railroad. Worked by P. and H. McKinney Company, Vandalia, Illinois. Sample is pit run from 15-foot section. Extent, 240,000 to 600,000 tons. Sand used for heavy gray iron work. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Sample No. 164: SE. 1/4 NE. 1/4 sec. 14, T. 6 N., R. 1 E. One-half mile southwest of Bluff City siding of Vandalia Railroad. Worked by Eugene Stultz, Mulberry Grove, Illinois. Produced for medium gray iron work. Sample from several channels in 3-foot section. Extent, 20,000 to 100,000 tons. Formation, wind blown sand capping east valley wall of Kaskaskia River. Contains weathered bond.

Sample No. 165: Location same as No. 164. Produced for heavy gray iron work. Sample taken from several channels in lower 5 feet of 9-foot section. Upper 4 feet extremely heavy sand. Extent, 80,000 to 380,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond. Exposed in bluff at lower elevation than deposit from which No. 164 was taken.

Sample No. 169: SW. 1/4 NE. 1/4 sec. 32, T. 6 N., R. 1 W. Two miles east of Mulberry Grove, one-half mile east of siding on Vandalia Railroad. Worked by Coarse Red Molding Sand Company, Mulberry Grove, Illinois. Sample of produced grade, taken from partially loaded cars. Production for heavy gray iron work. Pit section 7 to 10 feet. Extent, 52,000 to 100,000 tons. Formation, Illinoian fluvio-glacial sands containing weathered bond.

Gallatin County

Sample No. 190: S. 1/2 sec. 21, T. 9 S., R. 9 E. One mile east of Junction sidings of Louisville and Nashville and Baltimore and Ohio railroads. Unworked deposit. Owner's name unknown. Sample taken from several channels in upper 2 feet of total 6-foot section, exposed in roadcut. Extent of this grade 40,000 to 200,000 tons. Locality favorable for other deposits. Formation, wind blown sands mantling west slope of Shawneetown Hills. Sands contain weathered bond.

Sample No. 191: Location same as No. 190. Sample taken from lower 4 feet of total 6-foot section. Directly underlies No. 190. Extent of this grade 80,000 to 500,000 tons.

Hancock County

Sample No. 137: W. 1/2 NE. 1/4 sec. 2, T. 7 N., R. 7 W. One-eighth mile east of Dallas City siding of Santa Fe Railroad. Worked by Purity Molding Sand Company, Dallas City, Illinois. Sample taken from partially loaded car. Grade "No. 2." Extent, 12,000 to 20,000 tons. Formation, wind blown sands and silt on slope of east valley wall of Mississippi River.

Sample No. 149: Same location as No. 137. Sample taken from bin of Brass Foundry Company, 711 S. Adams St., Peoria, Illinois. Used for brass work.

Henderson County

Sample No. 86: Location same as No. 133. Sample taken from bin of Marseilles Plant, East Moline, Illinois. Used for medium gray iron work.

Sample No. 101: Location same as No. 133. Sample taken from bin of Frank Foundries, Moline, Illinois. Used for medium gray iron work.

Sample No. 128: NW. 1/4 NE. 1/4 sec. 15, T. 10 N., R. 5 W. One-fourth mile east of Gladstone siding of Chicago, Burlington and Quincy Railroad. Worked by W. H. Graham. Total pit section 16 feet. Sample taken from lower 5 feet of section. Slightly calcareous. Extent, 16,000 to 50,000 tons. Formation, wind blown silt capping east valley wall of Mississippi River. Contains primarily deposited bond.

Sample No. 130: W. 1/2 SE. 1/4 sec. 16, T. 10 N., R. 5 W. One mile south of Gladstone siding of Chicago, Burlington and Quincy Railroad. Worked by J. T. Galbraith. Sample from partially loaded car. Section 3 to 5 feet worked. Used for gray iron and brass. Extent, 24,000 to 50,000 tons. Formation, slope wash deposited at base of east valley wall of Mississippi River.

Sample No. 131: E. 1/2 sec. 11, T. 10 N., R. 5 W. On siding of spur of Chicago, Burlington and Quincy railroad. Worked by Monmouth Stone Company. Sample taken from several channels in total 4-foot pit section. Extent, 5,000 to 15,000 tons. Formation, wind blown sands and silts on hilltops adjacent to Mississippi Valley.

Sample No. 132: NW. 1/4 SE. 1/4 sec. 20, T. 10 N., R. 5 W. Two miles southwest of Gladstone siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name unknown. Sample taken from several channels in 2- to 3-foot section. Extent, 3,000 to 8,000 tons. Locality favorable for similar deposits. Formation, wind blown sand in dune on valley flat of Mississippi River. Contains weathered bond.

Sample No. 133: S. 1/2 NW. 1/4 sec. 31, T. 8 N., R. 6 W. Two and one-half miles east of Dallas City siding of Santa Fe Railroad

Worked by Purity Molding Sand Company, Dallas City, Illinois. Sample from 2 1/2-foot pit section used to produce grade "No. 2 open." Extent of whole deposit 30,000 to 80,000 tons. Formation, wind blown sands and silts on slope of east valley wall of Mississippi River. Sample is combination of weathered bond and primary bond sands interbedded in the section.

Sample No. 134: Location same as No. 133. Sample taken from 2-foot pit section used to produce grade "No. 1 open." Formation, same as No. 133. A less silty section.

Sample No. 142: Location same as No. 131. Sample taken from bin of Gem City Stove Company, Quincy, Illinois. Has been used for stove plate.

Sample No. 176: Location same as No. 133. Sample taken from bin of Eagle Foundry Company, Belleville, Illinois. Used for stove plate.

Henry County

Sample No. 76: SW. 1/4 sec. 2, T. 17 N., R. 1 E. One-half mile north of Colona siding of Chicago, Rock Island and Pacific Railroad. Worked by C. E. Oberlaender and Company. Sample taken from several channels in 1- to 3-foot pit section. Coarser phase. Extent of deposit 12,000 to 20,000 tons. Formation, wind blown sands and silts capping top of valley wall of Green River. Deposit exceedingly variable in texture. All sands produced are combinations of weathered and primary bond sands.

Sample No. 77: Location same as No. 76. Sample taken from single hole dug in upper 2 1/2 feet of 4-foot section.

Sample No. 83: Location same as No. 76. Sample taken from bin of John Deere Harvester Works, East Moline, Illinois. Used for medium gray iron work.

Sample No. 88: Location same as No. 76. Sample taken from bin of Union Malleable Company, East Moline, Illinois. Sold as "No. 5."

Sample No. 93: SW. 1/4 SW. 1/4 sec. 11, T. 17 N., R. 2 E. One-half mile south of Colona. Unworked deposit. Owner's name not known. Total 4-foot section; 1 foot coarse sharp, 1 foot fine heavy, and 2 feet coarse with medium bond. Sample 40 per cent sharp basal sand and 60 per cent heavy top sand. Total extent 18,000 to 30,000 tons. Formation, wind blown sand on valley flat of Green River. Contains weathered bond.

Sample No. 94: Same location as No. 93. Same section. Sample from heavy layer only.

Sample No. 95: Same location as No. 93. Same section. Sample from several channels in total 4-foot section.

Sample No. 99: Location same as No. 76. Sample taken from bin of Moline Plow Company, Moline, Illinois. Sold as "No. 6." Used for medium gray iron work.

Sample No. 111: N. 1/4 sec. 10, T. 17 N., R. 2 E. Three miles east of Green River siding of Chicago, Rock Island and Pacific Railroad. Adjacent to tracks of Chicago, Rock Island and Pacific Railroad. Unworked deposit. Owner's name unknown. Sample taken from several channels of 3-foot section exposed in roadcut. Extent, 30,000 to 240,000 tons. Locality favorable for similar deposits. Formation, low terrace deposit in valley of Green River. A waterlaid sand containing primarily deposited sand.

Sample No. 112: SE. 1/4 SW. 1/4 sec. 7, T. 17 N., R. 2 E. Three-fourths of a mile southeast of Green River siding of Chicago, Rock Island and Pacific Railroad. Abandoned pit. Mr. H. Stevens, owner. Sample taken from several channels in total 2- to 4-foot section. Extent, 40,000 to 100,000 tons. Formation, wind blown sand on upper terrace of Green River. Contains weathered bond.

Jackson County

Sample No. 182: SW. 1/4 NE. 1/4 sec. 16, T. 9 S., R. 3 W. Adjacent to Sand Ridge siding of Illinois Central Railroad. Unworked deposit. Owner's name unknown. Sample from total 6-foot section. Extent, 60,000 to 480,000 tons. Formation, terrace sand on terrace between Big Muddy and Mississippi rivers. Contains weathered bond but also has some layers containing primary bond. Appears remarkably uniform for such a large waterlaid deposit.

Jo Daviess County

Sample No. 61: SW. 1/4 NW. 1/4 sec. 9, T. 27 N., R. 1 E. One-eighth mile west of Aiken siding of Chicago, Great Western Railroad. Worked by Frank Einsweiler and Sons, Galena, Illinois. Sample taken from several channels in total 3-foot pit section of finer phase. Extent of deposit 24,000 to 40,000 tons. Formation, terrace sands of Mississippi River.

Sample No. 62: Location same as No. 61. Sample taken from several channels in total 2-foot pit section of coarser phase.

Sample No. 63: NW. 1/4 NW. 1/4 sec. 22, T. 27 N., R. 1 E. One mile southwest of Rice Station of Chicago Great Western Railroad. Unworked deposit. Owner's name unknown. Sample from single channel in 12-foot section. Extent, 200,000 to 1,000,000 tons. Formation, wind blown, calcareous silt or loess capping hilltops. Contains primarily deposited bond.

Kane County

Sample No. 2: SE. 1/4 NW. 1/4 sec. 1, T. 40 N., R. 8 E. Adjacent to spur of Chicago and Northwestern Railroad. Worked by G. J. Van Wicklin. Sample taken from partially loaded car. Pit section 3 to 5 feet. Extent, 40,000 to 80,000 tons. Formation, wind blown sands which mantle slope of east valley wall of Fox River.

Sample No. 5: NE. 1/4 SW. 1/4 sec. 3, T. 38 N., R. 8 E. One-fourth mile to North Aurora siding of Chicago and Northwestern Railroad. Worked by Peter Hettinger, North Aurora. Sample taken from several channels in total 4 1/2-foot pit section. Extent, 5,000 to 20,000 tons. Formation, wind blown sand on slope of east valley wall of Fox River.

Sample No. 6: NE. 1/4 SE. 1/4 sec. 33, T. 39 N., R. 8 E. One-third mile north of Sperry Company foundry, North Aurora. Worked by Sperry Company for foundry use. Medium gray iron work. Sample taken from foundry bin. Pit section 2 to 3 feet. Extent, 5,000 to 10,000 tons. Formation, wind blown sand on terrace of Fox River.

Sample No. 7: SW. 1/4 NE. 1/4 sec. 16, T. 42 N., R. 8 E. One mile west of Carpentersville siding of Chicago and Northwestern Railroad. Worked by Frank Vogel. Sample taken from partially loaded car. One- to four-foot pit section. Extent, 8,000 to 30,000 tons. Formation, wind blown sands and silts capping hilltop near crest of moraine.

Sample No. 8: SW. 1/4 NE. 1/4 sec. 15, T. 42 N., R. 8 E. Three-quarters mile north of Carpentersville siding of Chicago and Northwestern Railroad. Worked by Frank Vogel. Sample taken from several channels in several small openings. Pit sections 1 to 4 feet. Extent, 15,000 to 40,000 tons. Formation, wind blown sand mantling slope of valley tributary to Fox River valley.

Sample No. 38: Location same as No. 2. Sample taken from bin of International Harvester Company, Chicago, Illinois. Used for medium gray iron work.

Kendall County

Sample No. 19: NW. 1/4 NE. 1/4 sec. 34, T. 37 N., R. 6 E. One and one-fourth miles south of Plano siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name unknown. Sample from several channels in 2- to 3-foot sections exposed in hillside. Bond variable. Extent, 2,000 to 20,000 tons. Locality favorable for similar deposits. Formation, wind blown sand on slopes and ridges.

La Salle County

Sample No. 126: SW. 1/4 NW. 1/4 sec. 14, T. 33 N., R. 2 E. On spur of Chicago, Rock Island and Pacific Railroad. Silica sand pit worked

by Higbee Canyon Sand Company, Ottawa, Illinois. Sample from iron-stained cap rock. Ordinarily sold as steel sand. Bond and permeability tested wet only. Formation, St. Peter sandstone.

Lawrence County

Sample No. 195: NW. 1/4 SW. 1/4 sec. 3, T. 3 N., R. 11 W. One and one-fourth miles east of Lawrenceville siding of Baltimore and Ohio Railroad. Deposit adjacent to Baltimore and Ohio right-of-way. Unworked deposit. Owner's name unknown. Sample taken from several channels in total 3-foot section. Extent, 30,000 to 120,000 tons. Locality favorable for similar deposits. Formation, wind blown sands on terrace of Wabash River. Contains weathered bond only.

Madison County

Sample No. 172: NW. 1/4 SE. 1/4 sec. 29, T. 3 N., R. 8 W. One mile north of siding. Worked by Commercial Foundry Sand Company, Collinsville, Illinois. Production for light gray iron, brass and aluminum work. Sample taken from several channels in 2-foot lime-free portion of 4-foot pit section. Sample not a grade as produced but is grade which could be produced in limited quantity. Deposit variable in texture both vertically and horizontally. Extent of any one grade impossible to estimate. Sand of all types 20,000 to 60,000 tons. Formation, wind blown sands and silts on slope of east valley wall of Mississippi River. Interbedded textures make any sand produced a combination of weathered bond sand and a primarily deposited bond sand.

Sample No. 173: Location same as No. 172. Sample from several channels in 2-foot section of calcareous sand directly overlying the section represented by No. 172. Sample not a produced grade. Total 4-foot section is worked for a produced grade. Formation, same as No. 172.

Sample No. 175: Location same as No. 172. Coarsest grade produced. Sample taken from several channels of 3-foot lime-free pit section. Not more than 2,000 tons of this grade available. Formation, same as No. 172.

Marshall County

Sample No. 127: SW. 1/4 NE. 1/4 sec. 4, T. 30 N., R. 2 W. Two miles east of Henry siding of Chicago, Rock Island and Pacific Railroad. Unworked deposit. Owned by Peter Hank. Sample from single dug hole in upper 2 1/2 feet of total 10-foot section. Lower part of section uniform with sample. Extent, 3,000 to 5,000 tons. Locality favorable for similar deposits. Formation, terrace remnant on east side of Illinois valley.

McHenry County

Sample No. 9: NE. 1/4 NW. 1/4 sec. 34, T. 43 N., R. 8 E. Adjacent to siding of Chicago and Northwestern Railroad. Worked by Garden City Sand Company, Chicago, Illinois. Sample taken from partially loaded car. Total pit section 4 feet. Extent, 50,000 to 100,000 tons. Formation, wind blown sand on Fox River terrace.

Sample No. 21: SW. 1/4 SE. 1/4 sec. 16, T. 43 N., R. 8 E. Adjacent to spur of Chicago and Northwestern Railroad. Unworked as molding sand deposit. Sand is overburden on gravel in pit of Consumer's Gravel Company, Chicago, Illinois. Sample taken from several channels in 2- to 3-foot section of finest phase. Extent, 80,000 to 200,000 tons. Formation, wind blown sand on gravel outwash plain.

Sample No. 22: Location same as No. 21. Sample taken from several channels in 3- to 6-foot section of coarsest phase.

Ogle County

Sample No. 54: S. 1/2 SE. 1/4 sec. 5, T. 25 N., R. 11 E. One mile southwest of Byron siding of Chicago Great Western Railroad. Unworked deposit. Owner's name unknown. Sample taken from 2-foot section exposed in roadcut. Lacking in bond. Surface clay directly overlying might be added to increase bond strength. Extent, 5,000 to 30,000 tons. Locality favorable for similar deposits. Formation, wind blown sands capping east valley wall of Rock River. Contains some weathered bond.

Sample No. 55: W. 1/2 SW. 1/4 sec. 7, T. 23 N., R. 11 E. One-eighth mile east of Honey Creek siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name not known. Sample from single dug hole in total 3-foot section. Extent, 60,000 to 120,000 tons. Locality favorable for other deposits. Formation, terrace sands on broad terrace of Kyte River. Wind blown sands containing weathered bond, mantle hill slopes to northeast.

Sample No. 57: W. center W. 1/2 sec. 31, T. 23 N., R. 8 E. Adjacent to paved road five miles south of Oregon siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name unknown Sample from several channels in total 2- to 3-foot section exposed in roadcut. Extent, 10,000 to 60,000 tons. Formation, wind blown sand on terrace remnant of Rock River. Sand is derived from St. Peter sandstone and contains weathered bond.

Peoria County

Sample No. 150: NW. 1/4 SE. 1/4 sec. 21, T. 9 N., R. 7 E. Two and one-half miles east of Edwards siding of Chicago, Burlington &

Quincy Railroad. One-eighth mile from Chicago, Burlington & Quincy Railroad right-of-way. Unworked deposit. Owner's name not known. Sample is from upper 3 feet of 10-foot section of uniform texture which is lower part of 25-foot section exposed on west valley wall of Kickapoo Creek. The stratum from which the sample was taken could not be worked alone because of the overburden 15 to 20 feet thick. Extent of total deposit 100,000 to 200,000 tons. Formation, fluvio-glacial sands and silts deposited in still water.

Sample No. 152: Location same as No. 150. Sample from calcareous upper 3 feet of 10-foot section of uniform texture. This stratum overlies that represented by No. 150 and is separated from it by 5 feet of very calcareous silt. An overburden at least 5 feet thick covers the entire section and increases to a maximum of 20 feet back from the section. Extent of deposit estimated on basis of quantity available with 5-foot overburden.

Sample No. 153: NW. 1/4 SW. 1/4 sec. 27, T. 9 N., R. 7 E. Two miles west of Pottstown siding of Chicago, Burlington and Quincy Railroad. Unworked deposit. Owner's name unknown. Sample from several channels in upper 4 feet of 15-foot section of uniform texture. Overburden from 3 to 8 feet. Sample slightly calcareous, some parts of section very calcareous. Extent, 60,000 to 200,000 tons. Formation, fluvio-glacial sands underlying high terrace level of Kickapoo Creek.

Sample No. 154: SW. 1/4 NW. 1/4 sec. 17, T. 8 N., R. 8 E. In south part of city of Peoria. Worked by William Worm. Sample taken from several channels in total pit section. Used for heavy gray iron. Extent, 5,000 tons. Formation, wind blown sand in low dunes on surface of terrace of Illinois River. Occasional dunes are present on terrace from Henry to Peoria. Contains weathered bond.

Pope County

Sample No. 184: NW. 1/4 SE. 1/4 sec. 2, T. 14 S., R. 5 E. One mile south of Brownfield siding of Illinois Central Railroad. Unworked deposit. Owner's name unknown. Sample from uppermost foot of 3-foot section. Extent of deposit of fine sands and silts 180,000 to 1,200,000 tons. Considerable variability in clay and silt content from place to place. Formation, waterlaid fine sands and silts in abandoned river channel.

Sample No. 185: Location same as No. 184. Sample taken from lower 2 feet of 3-foot section.

Sample No. 186: Location same as No. 184. Sample from total 3-foot section in addition to six-inch surface layer, which contains little or no humus.

Sample No. 187: NW. 1/4 NE. 1/4 sec. 15, T. 14 S., R. 6 E. Two and one-half miles south of Homberg siding of Illinois Central Railroad.

Unworked deposit. Owner's name unknown. Sample from several channels in total 3- to 4-foot section. Extent, 5,000 tons. Locality favorable for similar deposits. Formation, low terrace deposits of abandoned river channel.

Sample No. 188: NW. 1/4 SE. 1/4 sec. 4, T. 14 S., R. 6 E. Adjacent to Homberg siding of Illinois Central Railroad. Unworked deposit. On right-of-way of Illinois Central Railroad. Sample from several channels in total 2-foot section. Extent, 5,000 tons. Locality favorable for similar deposits. Formation, wind blown sand in dunes on highest terrace of abandoned river channel.

Sample No. 189: NE. 1/4 NW. 1/4 sec. 2, T. 13 S., R. 5 E. Two and one-half miles south of Brownfield siding of Illinois Central Railroad. Part of deposit mentioned under No. 184. Sample from single dug hole in 3-foot total section. Surface silt not included.

Pulaski County

Sample No. 183: NW. 1/4 NE. 1/4 sec. 22, T. 15 S., R. 1 W. One-half mile south of Pulaski. Sample contains only iron oxide bond. From deposit of no commercial value. Formation, Tertiary sands.

Randolph County

Sample No. 181: SW. 1/4 NE. 1/4 sec. 28, T. 7 S., R. 6 W. Adjacent to Clores siding of Wabash, Chester and Western Railroad. Abandoned pit. Owner's name not known. Sample taken from upper 3 feet of 7-foot section. Extent, 20,000 to 50,000 tons. Formation, interbedded sands and silts on terrace of St. Mary's River. "Vegetable" or reduced clay bond.

Rock Island County

Sample No. 78: W. 1/2 sec. 3, T. 17 N., R. 2 W. Deposit adjacent to siding of Chicago, Rock Island and Pacific Railroad. Worked by Rock Island Molding Sand Company, Rock Island. Sample taken from 2½-foot pit section. Extent of deposit 120,000 to 600,000 tons. Formation, alluvium. Has "vegetable" or reduced clay bond. Deposit subject to the textural variations normal to deposits containing primarily deposited bond.

Sample No. 79: Location same as No. 78. Sample from dug hole in 2-foot section.

Sample No. 84: Location same as No. 102. Sample taken from bin of John Deere Harvester Works, East Moline. Used for light castings and as core filler.

Sample No. 85: Exact locality unknown. Reported to come from small island in Mississippi River. Was used locally at one time. Locally called "Mud Island" sand. Sample taken from remnant in bins of John

Deere Harvester Works, East Moline. Formation, apparently alluvium. Has "vegetable" or reduced clay bond. Bond primarily deposited.

Sample No. 102: NE. 1/4 NW. 1/4 sec. 14, T. 17 N., R. 2 W. One-eighth mile from siding of Chicago, Rock Island and Pacific Railroad. Worked by T. B. and S. S. Davis. Total section 15 to 20 feet. Sample taken from bin of Frank Foundries, Moline. Used for small castings and for core filler. Extent of deposit, 5,000 to 15,000 tons. Formation, wind blown silts on slope of north valley wall of Rock River. Bond primarily deposited. Calcareous except at base of section.

Sample No. 105: SW. 1/4 NW. 1/4 sec. 34, T. 18 N., R. 2 W. On the property of and adjacent to Blake Foundries Specialty Company, Rock Island. Sample taken from lower 3 feet of total 7-foot section. Used for light and medium castings. Formation, alluvium. Contains "vegetable" or reduced clay bond.

Sample No. 106: NW. 1/4 SW. 1/4 sec. 29, T. 18 N., R. 1 E. Adjacent to siding of Chicago, Rock Island and Pacific Railroad. Worked by Rock Island Molding Sand Company. Sample from several channels in total 2-foot section. Extent, 10,000 to 60,000 tons. Formation, sands in terrace remnant of old channel.

Sample No. 110: SE. 1/4 SW. 1/4 sec. 22, T. 17 N., R. 2 W. One and one-fourth miles west of Milan. Adjacent to Chicago, Rock Island and Pacific Railroad right-of-way. Unworked deposit. Owner's name unknown. Sample from single dug hole in 3-foot section. Extent, 9,000 to 20,000 tons. Locality favorable for similar deposits. Formation, fine sands and silts on broad terrace of Rock River.

Sangamon County

Sample No. 156: SW. 1/4 NE. 1/4 sec. 4, T. 17 N., R. 4 W. One-fourth mile northwest of Spaulding siding of Illinois Central Railroad. Unworked deposit. Owner's name unknown. Sample from several channels in 2- to 3-foot section, exposed in roadcut. Extent, 10,000 to 15,000 tons. Formation, wind blown sand capping east valley wall of Sangamon River. Contains weathered bond.

St. Clair County

Sample No. 180: NE. 1/4 SE. 1/4 sec. 7, T. 2 N., R. 8 W. One-eighth mile from Caseyville siding of Baltimore and Ohio Railroad. Owned and worked by O. J. Long, Caseyville. Sample from calcareous lower 6 feet of 18-foot section. Extent, 10,000 tons. Formation, wind blown silt or loess on slope of east valley wall of the Mississippi.

Shelby County

Sample No. 196: T. 10 N., R. 4 W. Two and one-half miles northwest of Fancher. One-half mile east of Kaskaskia River. Forest Howe,

owner. Sample from dug hole in 2½-foot section. Extent, 12,000 tons. Formation, wind blown sand capping hilltop. Contains weathered bond.

Tazewell County

Sample No. 155: NE. 1/4 SW. 1/4 sec. 13, T. 25 N., R. 5 W. Three miles north of Pekin. One-fourth mile east of Chicago, Peoria and St. Louis Railroad right-of-way. Unworked deposit. Owner's name unknown. Sample from several channels in 2- to 4-foot section exposed in roadcut. Extent, 200,000 to 500,000 tons. Locality very favorable for similar deposits. Formation, wind blown sand on terrace of Illinois River. Contains weathered bond.

White County

Sample No. 192: SE. 1/4 SW. 1/4 sec. 8, T. 5 S., R. 10 E. One and one-half miles east of Carmi siding of Big Four Railroad. Unworked deposit. Owner's name unknown. Sample from total 3½-foot section; 1½ feet very heavy, 2 feet open. Extent, 42,000 tons. Several deposits in locality. Formation, wind blown sand in dunes on terrace of Wabash River. Contains weathered bond.

Sample No. 193: NW. 1/4 SE. 1/4 sec. 11, T. 5 S., R. 10 E. Three and one-half miles southeast of Simpson siding of Big Four Railroad. Sample of several channels in total 3½-foot section. Extent, 40,000 to 100,000 tons. Locality favorable for similar deposits. Formation same as No. 192.

Sample No. 194: S. 1/2 sec. 29, T. 3 S., R. 11 E. One and one-fourth miles south of Grayville siding. Unworked deposit. Owner's name unknown. Sample from several channels in 2- to 4-foot section. Extent, 20,000 to 240,000 tons. Locality favorable for similar deposits. Formation, wind blown sand on terrace of Wabash River.

Whiteside County

Sample No. 65: SW. 1/4 NW. 1/4 sec. 25, T. 21 N., R. 5 E. One-eighth mile west of Round Grove siding of Chicago and Northwestern Railroad. Owner, Clare Knox. Lessee, Garden City Sand Company. Sample from upper 5 feet of total 10-foot pit section, calcareous. Extent, 24,000 to 50,000 tons. Formation, wind blown silt or loess capping ridge.

Sample No. 66: Location same as No. 65. Sample from calcareous lower 5 feet of total 10-foot pit section.

Sample No. 68: NE. 1/4 NW. 1/4 sec. 32, T. 21 N., R 4 E. Three miles north of Fenton siding. Deposit adjacent to Chicago, Burlington and Quincy right-of-way. Unworked deposit. Owner, Harry Hanzinga, Fenton. Sample from several channels in 2-foot section exposed in roadcut. Extent, 48,000 to 80,000 tons. Formation, wind blown sand on southeast valley wall of abandoned channel.

Sample No. 69: Location same as No. 68. Sample from several sections at higher level.

Will County

Sample No. 11: S. 1/2 sec. 18, T. 32 N., R. 10 E. One-fourth mile from siding of Wabash Railroad. Worked by Larson and Larson. Sample taken from partially loaded car. Pit section 2 to 4 feet. Extent, 40,000 tons. Formation, sand terrace of Kankakee River. Weathered bond.

Sample No. 12: S. 1/2 sec. 18, T. 32 N., R. 10 E. One-eighth mile west of Wabash Railroad siding. Worked by Riverside Sand Company, Custer Park, Illinois. Sample taken from partially loaded car. From 3-foot pit section. Extent, 20,000 to 60,000 tons. Formation, wind blown sand on terrace of Kankakee River.

Sample No. 13: Location same as No. 12. Sample from several dug holes in 2-foot section. Formation same as No. 12.

Sample No. 15: Location same as No. 12. Sample taken from dug hole in upper 2 feet of 4- to 6-foot section underlying pit sections mentioned under Nos. 12 and 13. Extent, 10,000 to 15,000 tons. Formation, terrace sands of Kankakee River. Contain weathered bond.

Sample No. 39: E. 1/2 sec. 12, T. 33 N., R. 9 E. One-eighth mile east of siding of Chicago and Alton Railroad. Worked by Rockton Molding Sand Co., Rockton, Illinois. Sample taken from several channels in 2½-foot section exposed in roadcut. Extent, 32,000 to 120,000 tons. Formation, wind blown sand mantling slope at east edge of wide flat. Weathered bond.

Sample No. 40: Location same as No. 39. Sample taken from several channels in 2-foot section of second roadcut.

Winnebago County

Sample No. 46: NE. 1/4 sec. 25, T. 46 N., R. 1. E. One mile south of Chicago, Milwaukee and St. Paul Railroad siding. Worked by Rockton Molding Sand Company, Rockton, Illinois. Sample taken from 2-foot pit section. Extent of whole deposit 50,000 to 300,000 tons. Formation, wind blown sands on slope and capping valley wall of Rock River.

Sample No. 47: Location same as No. 46. Sample taken from dug hole in upper 3 feet of 5-foot section. From upper slopes.

Sample No. 48: Location same as No. 46. Sample from 2-foot pit section in abandoned opening.

Sample No. 49: Location same as No. 46. Sample dug from 3-foot pit section by machine. This material is mechanically mixed with No. 46 to form one produced grade.

Sample No. 50: S. 1/2 sec. 24, T. 46 N., R. 1 E. Worked by Rockton Molding Sand Company, Rockton, Illinois. Sample from lower 6 feet of 8-foot pit section. Calcareous. Extent, 5,000 tons. Formation, wind blown silt or loess on slope of south valley wall of Rock River.

SANDS USED IN ILLINOIS PURCHASED OUTSIDE OF STATE

ALBANY, NEW YORK, NO. 1

Sample No. 180: Decatur Malleable Iron Company, Decatur, Illinois. Used for bond renewal and for small castings.

ALBANY, NEW YORK

Sample No. 103: Rock Island Stove Company, Rock Island, Illinois Used for stove plate.

Sample No. 104: Rock Island Stove Company, Rock Island, Illinois. Used for stove plate.

BAUMAN, INDIANA

Sample No. 25: Houghland and Hardy, Evansville, Indiana. Sample from Greenlee Brothers, Chicago, Illinois.

Sample No. 30: Houghland and Hardy, Evansville, Indiana. Western Foundry Company, Chicago. Light brass and aluminum casting.

BELOIT, WISCONSIN

Sample No. 24: Greenlee Brothers, Chicago. Used for heavy castings.

BELOIT, WISCONSIN, "NORTHWESTERN"

Sample No. 35: Crane Company, Chicago. Used for medium heavy castings.

CONNEAUT, OHIO, "NASH"

Sample No. 27: Western Foundry Company, Chicago. Used for slightly heavier work than No. 30.

BAUMAN, INDIANA, AND CONNEAUT, OHIO

Sample No. 28: Half and half mix made for some types of work. Western Foundry Company, Chicago.

CONNEAUT, OHIO

Sample No. 91: Tri-City Malleable Company, Moline, Illinois. Not suitable for malleable work.

NEWPORT, KENTUCKY, "DYETON"

Sample No. 34: Crane Company, Chicago. Used for light work.

NEWCASTLE, INDIANA, "BRADFORD"

Sample No. 33: Crane Company, Chicago. Used for medium weight castings.

Sample No. 36: National Malleable and Steel Casting Company, Chicago. Used for very heavy work.

Ridgeway, Pennsylvania

Sample No. 198: American Refractories Company. Synthetic sand with fire clay bond. Sample sent in.

Zanesville, Ohio

Sample No. 29: Western Foundry Company. Used for heavy castings and for opener with close sands.

Sample No. 32: Western Foundry Company, Chicago. Used for medium work.

Table I. **Results of tests on Illinois molding sands**[1]

Lab. No.	County[2]	Grade if Used	Screen Analysis												Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total					
139	Adams........	Produced . (Calcium carbonate present).	....	....	....	.6	2.6	1.6	1.2	2.7	2.4	75.3	13.0	99.4	4 6 8	231.6 238.3 **254.9**	3.7 **3.8** 3.6	14.3	4.6
52	Bond..........	Produced..	....	....	.1	.3	40.3	21.1	8.6	5.1	1.0	4.9	17.6	99.0	4 6 8	...... **312.3** 276.5	**83.6** 69.6 54.5		89.5
53	Bond..........	Produced..	....	....	.02	.6	39.0	14.2	5.1	4.1	1.1	16.7	18.8	99.62	4 6 8	...... **235.2** 210.3	**47.8** 44.0 37.4		19.8
100	Bond..........	Produced..	2.0	.5	1.6	4.7	31.8	13.6	10.2	4.2	.9	8.7	21.1	99.3	4 6 8	314.2 **321.5** 306.5	**92.8** 80.5 51.2		60.5
166	Bond..........	Possible...	....	1.0	1.4	4.0	42.8	18.6	8.2	4.6	1.4	3.8	14.0	99.8	4 6 8	**302.4** 289.1 212.7	**92.8** 83.5 56.2	32.2	82.4
167	Bond..........	Produced..	....	.6	.6	3.4	31.0	15.8	9.8	11.0	3.2	7.6	16.0	99.0	4 6 8	**336.7** 311.1 292.7	46.6 **48.6** 30.3		30.9
168	Bond..........	Produced..	....	.2	.4	.8	27.8	15.6	9.2	6.4	.8	10.0	28.0	99.2	4 6 8	336.6 325.7 **346.4**	77.6 **78.8** 41.5		121.6
170	Bond..........	Produced..	....	2.2	4.0	9.8	18.0	8.8	13.8	3.4	.8	13.4	25.0	99.2	4 6 8	281.0 303.1 **319.0**	66.3 **86.7** 76.8	4.9	108.0
171	Bond..........	Possible...	....	.2	3.0	24.6	45.0	1.8	1.0	1.0	.2	4.0	18.4	99.2	4 6 8	299.4 **336.6** 326.1	**432.0** 248.6 152.5	28.1	378.7
179	Bond..........	Produced..	.5	.5	.9	2.0	39.0	26.2	6.4	2.2	.4	4.4	16.4	98.4	4 6 8	**290.0** 278.1 254.7	**104.4** 96.4 62.8	-	105.3
43	Boone.........	Possible...	....	....	.8	7.2	37.4	11.2	4.6	3.4	1.2	10.4	23.0	99.2	4 6 8	...... **329.7** 325.2	...... **83.5** 58.3		94.5
113	Bureau........	Possible...	....	....	....	1.0	34.6	21.6	11.0	7.2	1.8	12.0	10.0	99.2	4 6 8	**231.1** 185.3 147.4	**43.2** 39.2 26.7	25.6	23.2
114	Bureau........	Possible...	....	....	....	.6	30.6	25.8	10.4	7.8	2.4	9.4	12.0	99.0	4 6 8	**283.2** 232.3 174.4	**64.2** 43.2 29.9	19.8	28.2
115	Bureau........	Produced..	....	....	....	.4	26.8	22.4	9.4	5.8	1.8	13.4	19.0	99.0	4 6 8	245.8 **266.9** 251.0	**50.1** 41.8 37.4		23.8
116	Bureau........	Produced..	....	....	....	1.4	35.6	27.8	10.8	5.0	.6	6.3	11.6	99.1	4 6 8	**231.7** 183.4 138.5	**69.6** 54.5 42.5	16.5	53.9
117	Bureau........	Possible...	....	....	....	2.0	37.4	25.4	11.0	5.0	.6	5.4	12.4	99.2	4 6 8	**212.5** 171.0 133.5	**71.6** 51.2 36.9		45.3
138	Cass..........	Produced..	....	....	....	.02	14.2	19.2	14.6	7.2	3.3	26.6	14.8	99.92	4 6 8	**205.9** 192.7 167.8	**26.9** 19.7 15.1	**4.3** gain	20.7
143	Cass..........	Possible...	....	....	....	....	29.0	32.6	12.0	7.0	1.0	5.6	12.4	99.6	4 6 8	**254.8** 179.1 144.5	**61.1** 47.5 36.3	22.8	37.7
144	Cass..........	Possible...	....	....	....	....	18.0	22.6	12.8	9.4	2.6	18.2	16.0	99.6	4 6 8	**198.8** 191.7 156.6	19.4 **21.1** 18.3		10.6
145	Cass..........	Possible...	....	....	....	....	12.6	13.8	9.2	11.0	4.6	35.6	12.5	99.3	4 6 8	**216.0** 193.3 173.2	**9.9** 9.3 9.6		8.2

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table 1. **Results of tests on Illinois molding sands[1]—Continued**

Lab. No.	County[2]	Grade if Used	Screen Analysis On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total	Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
146	Cass..........	No Value (Calcium carbonate present)...	....	....	....	1.4	16.4	16.4	9.0	9.0	3.2	26.6	17.0	99.0	4 6 8	**196.4** 191.9 180.2	8.1 7.7 **8.3**		9.3
147	Cass..........	Possible?..	....	....	....	....	11.0	11.8	5.6	4.2	2.4	44.0	20.0	99.0	4 6 8	203.4 **251.1** 231.6	**4.5** 4.3 4.1		4.4
177	Cass..........	Produced..	....	....	....	.02	13.1	24.0	18.4	15.6	3.3	14.2	9.68	98.3	4 6 8	**186.1** 161.7 132.9	**30.6** 29.5 24.4		26.2
197	Clinton........	Possible?..	....	.3	.7	2.4	31.2	11.3	4.8	4.9	1.4	15.9	26.4	99.3	4 6 8	270.6 270.7 **279.3**	**56.8** 41.2 3.8		10.8
10	Cook..........	Possible...	....	....	....	....	5.0	21.0	20.6	19.0	3.4	7.4	22.6	99.0	4 6 8	312.7 **322.4** 309.3	**54.2** 43.7 33.5		31.4
37	Fayette.......	Produced..	....	....	....	.06	27.4	25.0	14.1	11.8	2.0	3.9	14.5	98.76	4 6 8	**254.1** 224.4 207.0	**71.6** 53.3 55.7		43.7
161	Fayette.......	Possible...	....	1.2	1.6	2.8	29.0	19.8	6.7	4.2	2.0	9.8	22.4	99.5	4 6 8	...... **319.2** 288.6	...... 50.0 **57.1**		71.4
162	Fayette.......	Possible...	....	.2	.2	1.8	37.8	23.0	9.6	8.4	2.0	5.0	11.0	99.0	4 6 8	**329.9** 326.0 314.2	**61.9** 57.3 49.0		55.2
163	Fayette.......	Produced..	....	1.8	3.8	15.4	45.0	9.0	3.0	2.4	.4	4.2	14.0	99.0	4 6 8	**284.8** 269.4 220.0	**182.9** 135.7 104.4		110.9
164	Fayette.......	Possible...	....	....	....	....	32.0	22.0	13.2	11.6	1.2	1.8	17.6	99.4	4 6 8	**341.3** 321.7 283.3	**100.3** 92.8 67.8		66.3
165	Fayette.......	Possible...	....	1.8	2.8	7.0	51.2	7.4	3.2	3.0	1.0	6.0	16.0	99.4	6 8 10	315.3 315.4 **339.9**	50.6 **70.4** 69.4		127.1
169	Fayette.......	Produced..	....	....	....	1.0	39.8	20.4	6.6	3.8	.4	6.4	20.6	99.0	4 6 8	**320.7** 301.7 295.4	72.0 **80.8** 59.2		49.7
190	Gallatin.......	Possible...	....	....	....	....	9.0	17.0	13.0	12.0	5.0	26.0	17.0	99.0	4 6 8	**181.5** 167.9 153.4	**18.0** 17.5 15.7	8.8	16.2
191	Gallatin.......	Possible...	....	....	....	....	11.0	21.4	16.0	13.0	4.0	11.4	22.6	99.4	6 8 10	**333.1** 326.0 320.6	**31.7** 26.7 21.4		26.9
137	Hancock......	"No. 2"...	....	....	....	....	.2	1.4	4.0	7.0	6.0	53.0	28.0	99.6	4 6 8	245.0 **282.1** 263.4	**7.5** **7.5** 7.2		7.2
149	Hancock......	Produced..	....	....	....	.04	1.8	3.0	3.1	6.8	4.4	64.2	16.4	99.74	4 6 8	255.0 **286.5** 257.0	**6.5** 5.4 4.2		6.4
86	Henderson.....	Produced..	....	.2	.02	.4	11.3	11.3	9.6	11.6	4.6	38.2	11.8	99.02	4 6 8	...... **212.9** 192.1	**12.5** 8.7 10.9		13.4
101	Henderson.....	Produced..	....	.1	.3	2.0	18.7	12.1	9.3	13.0	5.0	29.1	9.4	99.0	4 6 8	181.5 **197.8** 173.8	**13.2** 13.0 12.6		11.3
128	Henderson.....	Possible (Calcium carbonate present)...	....	....	....	....	....	.8	1.6	6.6	6.9	78.2	5.0	99.1	4 6 8	147.0 169.5 **172.8**	7.1 **7.2** 6.9		9.0

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table I. Results of tests on Illinois molding sands[1]—Continued

Lab. No.	County[2]	Grade if Used	Screen Analysis: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total	Water Per cent	Bond Strength	Permeability	Per Cent Loss Bond Strength at 600° F.	Base Permeability
130	**Henderson.....**	Produced..	....	....	....	2.2	16.0	13.0	7.6	8.2	2.8	31.8	17.6	99.2	4 6 8	225.7 **248.9** 221.9	**19.3** 18.1 15.7	11.4	12.1
131	**Henderson.....**	Possible...	....	....	....	....	14.0	15.4	9.0	7.4	3.0	29.4	21.0	99.2	4 6 8	278.2 **281.3** 266.8	21.4 **26.7** 21.1		11.9
132	**Henderson.....**	Possible...	....	....	....	4.2	32.0	7.4	3.4	8.4	3.4	18.2	22.2	99.2	4 6 8	...... **298.0** 269.4	...... **23.2** 16.5		14.7
133	**Henderson.....**	"No. 2 Open"...	....	....	....	....	5.4	6.6	6.3	11.8	6.2	40.4	22.4	99.1	4 6 8	237.2 **250.0** 241.6	**11.6** 10.4 5.7	21.1	8.4
134	**Henderson.....**	"No. 1 Open"...	....	....	....	.3	6.2	12.1	20.1	28.3	7.3	17.2	8.0	99.5	4 6 8	**188.4** 149.8 133.6	23.2 **25.6** 21.8		21.3
142	**Henderson.....**	Produced..	....	....	....	....	13.8	17.6	11.0	11.0	2.4	26.4	16.0	98.2	4 6 8	**230.0** 216.2 188.4	**18.5** 16.0 14.5		18.4
176	**Henderson.....**	Produced..	....	....	....	.1	8.3	12.3	14.9	21.8	7.6	27.9	5.8	98.7	4 6 8	**151.5** 147.9 136.1	**15.9** 14.5 13.7		14.5
76	**Henry.........**	Possible...	....	....	....	....	23.0	26.0	13.4	11.2	2.6	12.8	10.2	99.2	4 6 8	**204.7** 179.1 159.6	23.2 **28.5** 24.4		17.3
77	**Henry.........**	Possible...	....	....	....	1.6	27.0	17.4	7.4	4.6	1.4	21.0	18.0	98.4	4 6 8	189.6 **201.7** 186.6	9.8 12.2 **13.7**		7.6
83	**Henry.........**	Produced..	....	.1	.06	.3	13.5	17.4	12.6	10.1	2.9	27.3	14.1	98.36	4 6 8	**222.8** 214.8 209.7	15.7 **16.6** 12.6	25.7	13.7
88	**Henry.........**	"No. 5"...	....	....	....	.2	9.5	15.9	13.5	12.0	5.3	34.6	7.6	98.6	4 6 8	**234.4** 223.1 191.7	9.8 **10.2** 8.1	11.2	12.7
93	**Henry.........**	Possible?..	....	....	....	2.6	30.0	10.6	15.4	18.2	3.4	7.8	10.6	98.6	4 6 8	**209.8** 175.5 134.4	**35.3** 32.6 29.6	17.9	44.3
94	**Henry.........**	Possible?..	....	....	....	.4	17.4	17.8	18.0	19.6	4.0	10.0	12.0	99.2	4 6 8	**198.0** 188.4 156.6	**36.4** 34.8 30.9		36.8
95	**Henry.........**	Possible...	....	....	....	....	5.0	11.8	21.6	28.4	5.8	11.9	14.7	99.2	4 6 8	251.7 **262.4** 228.1	23.2 **27.8** 20.4		29.4
99	**Henry.........**	"No. 6"...	....	....	....	.4	16.4	25.2	15.6	10.0	3.0	17.2	11.4	99.2	4 6 8	**167.4** 158.7 136.2	23.2 **24.5** 20.0		16.4
111	**Henry.........**	Possible...	....	....	....	....	3.8	2.2	3.4	5.6	2.5	58.0	23.0	98.5	4 6 8	...... **292.5** 291.0	6.5 **8.0** 7.7	8.2	11.6
112	**Henry.........**	Possible...	....	....	....	....	2.0	30.8	31.4	15.4	2.4	4.2	13.0	99.2	4 6 8	**269.5** 242.2 188.7	49.7 **55.7** 34.4		43.3
182	**Jackson.......**	Possible...	....	....	....	....	15.4	17.4	15.6	17.4	5.4	11.2	16.6	99.0	4 6 8	**291.1** 253.4 224.2	**30.0** **30.9** 28.4	19.7	27.8
61	**Jo Daviess....**	Possible...	....	....	....	....	2.0	6.0	9.4	26.4	9.0	27.4	19.4	99.6	4 6 8	**317.7** 297.8 287.5	11.2 **12.2** 10.9	17.5	12.3
62	**Jo Daviess....**	Possible...	....	....	....	....	23.6	27.0	18.0	15.0	2.6	4.8	8.0	99.0	4 6 8	**220.4** 152.4 130.7	**52.2** **44.0** **41.8**		**47.6**

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table I. **Results of tests on Illinois molding sands[1]—Continued**

Lab. No.	County[2]	Grade if Used	Screen Analysis: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total	Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
63	Jo Daviess....	Possible (Calcium carbonate present)...	....	....	....	....	.4	.5	1.0	4.2	4.2	69.8	19.0	99.1	4 6 8	219.2 **256.6** 227.7	2.6 3.3 **3.4**		4.3
2	Kane..........	Produced..	....	....	....	1.6	27.0	5.8	3.6	2.6	1.4	29.4	28.0	99.4	4 6 8	310.3 **362.0** 337.3	20.6 **24.1** 20.4		13.7
5	Kane..........	Possible...	....	....	....	5.8	37.4	13.0	5.8	5.0	1.2	11.4	20.0	99.6	4 6 8	**262.1** 257.5 245.4	**48.2** 43.2 38.6		45.2
6	Kane..........	Produced..	....	....	....	3.0	31.2	11.4	4.0	3.6	1.8	22.8	21.4	99.2	4 6 8	228.5 271.8 **314.2**	12.1 **20.3** 15.9	15.3	27.8
7	Kane..........	Produced..	....	....	....	1.6	36.7	16.2	8.0	6.1	1.2	13.0	16.6	99.4	4 6 8	**237.9** 235.4 223.4	**58.3** 53.3 40.4		43.2
8	Kane..........	Produced..	....	....	....	1.4	23.3	15.4	7.6	6.3	1.7	21.4	21.7	98.8	6 8 10	245.3 **288.7** 281.5	28.8 **32.6** 8.7		35.8
38	Kane..........	Produced..	....	.02	.04	4.2	54.4	9.2	2.5	1.7	.5	11.1	15.1	98.76	4 6 8	194.3 **263.3** 166.5	**67.7** 62.7 44.8	9.2	37.6
19	Kendall.......	Possible?..	....	....	1.2	2.0	39.4	20.0	6.4	3.4	.4	2.8	23.8	99.4	4 6 8	**307.9** 258.6 202.2	**127.8** 96.7 53.8		66.3
126	La Salle......	Possible...	....	....	....	37.8	57.2	2.2	.6	.4	.1	.1	1.2	99.6	1 2 4	**66.9** 63.2 63.6	503.2 503.2 503.2		
195	Lawrence......	Possible...	....	....	....	.6	45.0	18.0	5.0	2.2	.4	2.0	26.0	99.2	6 8 10	**305.8** 292.0 245.4	**83.5** 71.6 43.2	35.5	53.1
172	Madison.......	Possible...	....	....	....	....	8.4	25.4	13.8	8.8	2.6	28.4	11.6	99.0	4 6 8	**235.7** 209.5 188.5	8.5 9.1 **9.2**		9.8
173	Madison.......	Possible (Calcium carbonate present)...	....	....	....	.2	8.2	13.0	8.3	8.7	3.8	45.0	12.4	99.6	4 6 8	**267.2** 254.5 231.0	6.5 **9.3** 6.7		9.2
175	Madison.......	Possible...	....	....	....	....	8.0	21.8	12.0	9.6	6.1	25.0	16.0	98.7	4 6 8	**259.8** 255.5 232.5	**22.4** 20.2 19.4		18.7
127	Marshall......	Possible...	....	....	....	....	3.8	15.3	18.7	17.3	2.6	14.2	27.2	99.1	4 6 8	...... 299.6 **306.1**	31.3 **35.7** 34.3	8.8	31.2
9	McHenry......	Produced..	....	....	....	1.6	19.2	17.2	12.2	7.2	11.7	16.8	12.6	98.5	6 8 10	194.6 231.6 **251.1**	11.1 **17.4** 15.5		13.5
21	McHenry......	Possible...	....	....	....	.4	6.4	5.0	5.2	10.0	8.8	38.0	25.6	99.4	4 6 8	285.0 290.6 **297.6**	**11.3** 9.6 7.6		8.5
22	McHenry......	Possible...	....	....	....	.8	19.0	12.8	7.4	10.4	5.0	24.0	19.6	99.0	4 6 8	...... **301.0** 268.6	...... **18.3** 15.6		9.
54	Ogle..........	Possible?..	....	....	.3	7.7	67.8	6.6	1.1	.7	.2	6.8	7.9	99.1	4 6 8	**150.4** 110.5	**125.3** 98.3 71.6		162.7
55	Ogle..........	Possible...	....	1.1	1.8	4.2	36.2	17.0	5.4	3.4	.6	19.1	10.6	99.4	4 6 8	**253.1** 252.7 233.6	30.6 **37.7** 27.9	10.5	17.2

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table 1. Results of tests on Illinois molding sands[1]—Continued

Lab. No.	County[2]	Grade if Used	Screen Analysis: On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total	Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
57	Ogle..........	Possible...	....	....	.04	7.6	59.0	4.0	1.0	.1	.1	7.0	20.0	99.2	4 6 8	**290.0** 265.9 278.9	**156.6** 100.3 89.5		189.2
150	Peoria.........	Possible...	....	....	....	....	.8	5.0	22.6	38.6	6.8	15.0	10.6	99.4	4 6 8	**141.8** 136.9 128.0	**21.6** 20.4 **21.6**	2.0 gain	20.2
152	Peoria.........	Possible (Calcium carbonate present)...	....	....	....	....	.7	2.6	11.1	32.6	10.6	35.8	5.0	98.4	4 6 8	127.9 **140.9** 140.8	13.4 **14.9** **14.9**		11.0
153	Peoria.........	Possible (Calcium carbonate present)...	....	....	....	....	1.6	6.4	13.2	25.0	6.8	36.8	9.0	98.8	4 6 8	151.6 **157.4** 147.1	9.3 9.6 **9.8**	16.9	12.9
154	Peoria.........	Possible	....	....	.6	22.2	55.3	3.8	1.6	1.8	.6	1.4	11.6	99.0	4 6 8	280.5 **284.9** 185.7	216.0 **251.6** 106.6		245.0
184	Pope..........	Possible...	....	....	....	.1	6.2	9.0	8.0	9.6	4.6	34.6	27.2	99.3	4 6 8 10	138.4 141.5 168.0 **183.8**	3.6 3.9 5.4 **6.8**		7.5
185	Pope..........	Possible...	....	....	....	....	7.8	11.2	6.8	8.4	22.4	21.8	20.2	98.6	8 10 11	268.9 290.2 **300.0**	12.7 13.7 **14.4**		6.7
186	Pope..........	Possible...	....	....	....	....	6.4	10.6	6.8	7.2	2.6	24.4	40.6	98.6	6 8 10 12	181.2 207.9 210.2 **220.9**	3.9 7.4 9.4 **10.2**	4.8	6.5
187	Pope..........	Possible...	....	3.0	15.4	28.4	18.2	6.8	4.4	4.0	1.0	3.6	14.4	99.2	4 6 8	**273.8** 249.6 233.7	**208.8** 156.6 104.4		113.4
188	Pope..........	Possible...	....	....	....	....	47.0	18.4	5.2	2.0	.2	4.0	22.6	99.4	6 8 10	**282.2** 270.0 242.3	**69.6** 62.6 41.2		60.5
189	Pope..........	Possible...	....	....	....	.2	1.4	.6	1.8	.5	1.4	54.7	38.4	99.0	4 6 8	158.2 212.0 **214.9**	1.1 1.5 **1.7**		4.3
183	Pulaski........	No value...	....	....	....	....	.6	2.8	23.0	54.0	5.4	3.4	10.0	99.2	4 6 8	**188.0** 143.9 116.4	**41.8** 36.8 33.4	21.5	40.1
181	Randolph.....	Possible...	....	....	....	1.4	1.0	1.2	3.4	15.0	7.8	43.2	26.1	99.1	6 8 10	190.1 **241.4** 226.3	6.6 7.3 **9.6**		10.3
78	Rock Island...	Produced..	....	....	....	....	5.1	9.4	18.5	22.8	9.6	26.0	7.4	98.8	4 6 8	190.8 197.2 **199.1**	**10.3** **10.3** 10.0	9.3	17.0
79	Rock Island...	Possible...	....	....	....	2.4	8.8	7.6	11.4	17.8	5.6	25.4	20.0	99.0	4 6 8	...... 203.7 **213.4**	14.3 **14.5** 11.0		12.0
84	Rock Island...	"Blackhawk" (Calcium carbonate present)...	....	.1	.04	1.3	7.5	4.2	4.8	11.0	7.7	57.8	4.7	99.14	4 6 8	151.9 156.3 **160.7**	8.0 **8.4** **8.4**		10.3
85	Rock Island...	"Mud Island"..	....	.1	.3	.3	2.7	13.5	21.9	17.6	3.8	24.2	14.8	99.2	4 6 8	241.8 **270.4** 255.0	**18.1** 16.9 15.5	14.5	15.7
102	Rock Island...	"Blackhawk" (Calcium carbonate present)...	....	....	....	....	.6	.8	1.2	4.2	4.4	78.8	9.7	99.7	4 6 8	181.3 **197.8** 173.8	4.1 4.4 **4.7**	1.9 gain	6.5

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table I. Results of tests on Illinois molding sands[1]—Continued

Lab. No.	County[2]	Grade if Used	Screen Analysis On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total	Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
105	Rock Island...	Possible...	....	....	....	.02	1.1	16.0	27.0	22.9	4.0	16.7	11.2	98.92	4 6 8	**208.6** 202.0 183.3	**20.2** 17.4 15.9		20.5
106	Rock Island...	Possible...	....	1.2	5.6	20.0	35.4	7.4	3.4	1.8	.8	6.2	17.6	99.4	4 6 8	209.9 **232.3** 215.8	32.2 38.6 **45.6**		50.1
110	Rock Island...	Possible...	....	....	....	1.2	9.8	7.1	7.4	11.8	19.8	33.8	8.2	99.1	4 6 8	236.4 **271.4** 261.8	4.4 4.6 **4.7**	7.7	8.4
156	Sangamon.....	Possible...	....	....	....	5.0	47.0	17.6	7.0	4.4	.4	1.4	16.2	99.0	4 6 8	**321.3** 301.3 243.6	**147.7** 104.4 92.8		92.4
180	St. Clair......	Possible (Calcium carbonate present)...	....	....	....	....	.2	.2	.2	.8	.8	89.0	8.2	99.4	4 6 8	145.0 **186.0** 172.6	4.3 4.5 **4.7**	5.0	5.1
196	Shelby........	Possible...	....	....	....	11.4	48.8	7.4	3.2	2.8	.6	.8	24.6	99.6	6 8 10	361.6 358.2 **370.2**	**188.3** 98.6 124.0	25.0	232.0
155	Tazewell......	Possible...	....	....	....	.6	15.2	19.0	15.2	9.2	1.6	13.8	24.6	99.2	6 8 10	238.7 **252.4** 215.9	22.7 **26.1** 19.2	4.1	31.7
192	White.........	Possible...	....	....	....	....	24.6	33.4	12.2	5.4	.6	4.0	19.0	99.2	4 6 8	**306.9** 284.3 254.4	**70.2** 63.9 45.8	21.8	33.3
193	White.........	Possible...	....	....	....	....	23.2	23.2	18.2	15.2	2.4	3.8	11.0	97.0	4 6 8	**247.7** 210.6 151.9	**46.8** 39.3 40.2		43.9
194	White.........	Possible...	....	....	....	....	7.0	22.0	23.0	21.4	4.4	5.0	16.6	99.4	4 6 8	315.9 **323.3** 283.7	**42.4** 41.2 37.9	14.5	31.3
65	Whiteside......	Possible (Calcium carbonate present)...	....	....	....	....	11.0	18.0	13.4	14.0	5.4	30.8	6.8	99.4	4 6 8	**154.1** 138.3 143.3	12.2 12.9 **13.4**		16.4
66	Whiteside.....	Possible. (Calcium carbonate present)...	....	....	....	....	11.0	11.8	8.8	13.0	7.0	39.2	8.2	99.2	4 6 8	**247.4** 172.2 154.2	8.1 9.0 **10.0**	32.2	13.6
68	Whiteside.....	Possible...	....	....	....	....	3.9	13.0	12.8	23.8	8.2	26.0	12.2	99.9	4 6 8	275.6 **322.9** 302.4	**15.3** 14.7 13.6		14.9
69	Whiteside.....	Possible...	....	....	....	....	2.2	10.8	17.0	25.0	8.2	20.6	15.4	99.2	4 6 8	**245.0** 222.6 196.1	13.7 **14.1** 13.9		15.5
11	Will...........	Produced..	....	....	....	.6	19.2	19.0	13.2	17.2	6.2	12.2	11.2	98.8	4 6 8	**241.9** 212.2 165.0	**32.2** 28.1 23.4		27.9
12	Will...........	Produced..	....	....	....	.8	19.0	16.0	11.9	15.6	5.2	11.6	19.0	99.1	4 6 8	162.1 **166.2** 136.9	21.5 **23.4** 22.0	13.9	14.1
13	Will...........	Produced..	....	....	....	....	12.8	14.2	15.8	10.4	8.4	28.8	9.0	99.4	4 6 8	131.7 **133.7** 127.3	11.0 12.6 **13.6**		14.4
15	Will...........	Possible...	....	....	....	.7	51.5	23.3	6.4	4.2	.5	.6	11.8	99.0	4 6 8	**267.4** 200.2 124.4	**139.2** 96.4 67.8		99.9
39	Will...........	Possible...	....	.2	1.8	6.4	38.0	13.4	6.6	4.6	1.0	7.0	20.0	99.0	4 6 8	...... **253.2** 248.0	...... **72.4** 51.2		88.6

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table 1. Results of tests on Illinois molding sands[1]—Continued

Lab. No.	County[2]	Grade if Used	Screen Analysis												Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total					
40	Will..........	Possible...	....	....	.4	4.4	33.0	16.0	7.0	5.4	7.0	6.8	19.0	99.0	4 6 8	243.9 **270.1** 237.4	**79.8** 73.9 36.8	5.1	87.0
46	Winnebago....	Possible...	....	....	....	.4	25.6	27.6	8.8	7.0	.8	13.0	16.8	99.2	4 6 8	**319.0** 305.0 299.5	**50.1** 41.8 33.9		52.6
47	Winnebago.....	Possible...	....	....	....	.3	29.0	17.0	8.0	7.0	1.6	12.8	22.8	98.5	6 8 10	308.6 316.7 **338.4**	14.0 16.2 **17.9**		36.9
48	Winnebago....	Possible...	....	....	....	.2	10.8	8.2	5.4	4.6	2.4	40.2	27.6	99.4	4 6 8	...... 177.6 **184.3**	6.0 9.4 **10.6**		13.2
50	Winnebago....	Possible.... (Calcium carbonate present)	....	....	....	....	3.0	2.8	2.4	5.8	5.0	69.4	11.0	99.4	4 6 8	**258.0** 243.3 231.9	**4.4** 4.2 3.9		5.1

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] Precise locations are given on pages 366 to 381.

Table 2. Results of tests on imported sands used in Illinois[1]

Lab. No.	Location[2]	Grade if Used	Screen Analysis												Water Per cent	Bond Strength	Permeability	Per cent Loss Bond Strength at 600° F.	Base Permeability
			On 6	On 12	On 20	On 40	On 70	On 100	On 140	On 200	On 270	Through 270	Clay	Total					
103	Albany, N.Y..	Produced	....	....	....	.5	6.7	7.4	13.9	21.5	7.5	22.1	19.6	99.2	4 6 8	145.3 **171.0** 148.4	8.9 13.3 **13.8**	8.9	15.2
104	Albany, N.Y..	Produced	....	....	....	....	1.5	4.9	8.8	21.4	13.7	37.4	11.2	98.9	4 6 8	...... **164.8** 153.6	10.0 11.6 **12.3**	2.6 gain	9.6
180	Albany, N.Y..	"No. 1"...	....	....	....	.2	1.3	2.9	9.5	29.0	15.9	34.4	5.9	99.1	4 6 8	140.3 144.2 **146.0**	**15.5** 13.7 14.2		14.9
25	Bauman, Ind..	Produced	....	....	....	....	.06	.04	.02	.04	.04	72.8	24.8	97.8	6 8 10	240.9 **263.7** 247.6	2.0 2.2 **2.8**	6.2	3.1
30	Bauman, Ind..	Produced	....	.02	.02	.04	.4	.7	1.3	5.5	4.9	70.2	15.2	98.28	4 6 8	165.3 202.2 **207.6**	2.8 3.7 **4.2**	2.3	8.9
24	Beloit, Wis....	Produced	....	....	.04	2.6	41.3	16.9	6.6	3.9	.1	13.4	13.0	97.84	4 6 8	**233.2** 220.2 171.0	**45.7** 34.8 18.3		40.9
35	Beloit, Wis....	"Northwestern"	....	.06	.1	1.1	19.5	8.9	4.3	3.0	1.3	33.2	28.2	99.66	4 6 8	264.9 270.8 **303.7**	17.3 16.3 **30.6**		11.1
27	Conneaut, Ohio	"Nash"	....	.4	.3	.5	3.9	8.0	26.1	24.8	3.7	20.8	10.1	98.6	4 6 8	...... 151.1 147.8	11.7 16.2 **19.0**	5.4	16.1
28	Bauman, Ind.. Conneaut, Ohio	Foundry Mix.....	....	.02	.1	.2	1.4	3.5	10.8	9.1	1.9	59.3	12.6	98.92	4 6 8	...... 168.5 **177.2**	3.9 4.6 **5.3**		5.3
91	Conneaut, Ohio	Produced	....	....	....	.04	1.2	2.	4.4	11.1	6.4	60.8	13.0	99.54	4 6 8	...... **254.2** 228.1	...... **7.7** 7.3		6.2
34	Newport, Ky..	"Dyeton"	....	.06	....	.04	.07	2.2	2.8	7.0	5.6	59.0	21.3	98.7	4 6 8	188.4 204.0 **233.8**	3.3 4.0 **4.5**		7.2
33	Newcastle, Ind.	"Bradford"	11.7	1.9	5.0	3.4	18.6	7.8	5.6	5.3	1.4	17.7	20.7	99.1	4 6 8	294.2 301.7 **316.2**	12.5 16.5 **30.7**		35.4
36	Newcastle, Ind.	"Bradford"	2.6	2.2	3.9	8.7	26.0	7.9	4.8	4.6	1.6	16.8	19.4	98.5	4 6 8	...... 330.3 **351.9**	44.8 58.3 **64.3**	37.3	75.0
198	Ridgeway, Pa.	Produced	....	....	....	18.0	50.0	6.0	2.6	3.0	.4	7.4	12.0	99.4	4 6 8	149.0 151.7 **165.6**	25.5 52.4 **61.9**	11.6	23.0
29	Zanesville, Ohio	Produced	....	.6	1.9	9.8	49.8	8.6	3.0	1.1	2.4	11.4	11.2	99.8	4 6 8	**231.3** 197.4 135.8	**77.5** 63.2 35.1	33.3	142.4
32	Zanesville, Ohio	Produced	....	.7	.6	1.9	18.4	10.7	6.7	5.7	2.7	35.6	16.1	99.1	4 6 8 10	145.4 166.7 202.1 **220.4**	**20.4** 15.9 11.1 9.7		16.1

[1] Bold face figures indicate the best developed bond strength and permeability.
[2] For further information regarding location, see pages 382 and 383.

Index–Part II

Authors' Index—Part II